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Editorial

Bridging Disciplines, Building Solutions: As the world navigates complex global challenges the limitations between the traditional core disciplines such as civil, computer, electrical and mechanical engineering are rapidly disappearing. Today, multidisciplinary engineering is no longer merely an academic concept; it is the foundation of innovation, integration, sustainability, and societal progress. Innovation occurs where multiple professions work together, and the integration of disciplines has become the hallmark of transformative engineering practices.

Multidisciplinary engineering is essential. New possibilities for exploration have been made possible by the widespread adoption of cutting-edge technologies like robotics, machine learning, Internet of Things, virtual reality, Generative AI, quantum computing, and more in all engineering disciplines. These technologies act as common platforms, bridging disciplines and encouraging unified development models. The combination of computer science and cognitive science (machine learning for human behaviour analysis), civil engineering with environmental sciences (green buildings), electronics engineering and artificial intelligence (embedded AI systems), materials science and nanotechnology (nanomaterials engineering), are few examples of how a multidisciplinary engineering collaboration promotes innovation. These hybrid domains are producing more flexible, sustainable, and user-friendly technologies rather than simply superior products. Engineers of the future must be multi-domain pioneering innovators with the ability to think holistically and see beyond barriers.

The training of engineers is also changing because of innovative educational techniques. Institutions should encourage project-based learning, interdisciplinary capstone projects, and collaborative research labs that unite students and faculty from multiple disciplines. This fosters a mindset which values differences in ideas, abilities, and viewpoints, which is vital for solving the real-world problems.

To provide a novel, scalable, and sustainable solutions, multidisciplinary engineering integrates the concepts of several fields, including mechanical, electronics, computing, materials science, and even life sciences. The issues we seek to address today, from smartwatches, health bands, 3D printing, robotic surgery, spaceX tech., hybrid vehicles, smart farming, and more necessitate the confluence of viewpoints, abilities, and information. This convergence is also extending into non-technical disciplines. The inclusion of management, economics, psychology, and design thinking into engineering solutions will help to make technology more accessible and socially responsible.

Uniting Disciplines to Solve Tomorrow's Challenges

New Delhi

30th June 2025

Editor

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Comparative Analysis of Advance Bridge Inspection Practices and Bridge Management System: Insights from India and the United States

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ABSTRACT

As bridges are a vital aspect of the transportation system and nation's economy, bridge inspections and bridge management systems play a role for ensuring the security, longevity, and operation of key infrastructure. This study evaluates the management systems and inspection practices for bridges in the US and India, two nations with different infrastructure issues and regulations. The research paper looks at significant matters such as data management systems, technologies, practices, and inspection frequency. While India frequently uses manual inspections and old procedures, impacted by limited assets and policy gaps, the United States uses innovative methods like digital twin technology, non-destructive testing, and sophisticated asset management platforms. The Indian Road Congress (IRC) visual inspection standards and the National Bridge Inspection Standards (NBIS) in the US are comprehensively evaluated. From an evaluation of global best practices and the identification of present errors, this study offers practical suggestions to enhance bridge management and monitoring in India. In the end, the study highlights how important an effective, adaptable strategy contributes to public safety and sustainable infrastructure development.

KEYWORDS : *Bridge inspection, Bridge health monitoring, New techniques.*

INTRODUCTION

Road transport is the most preferable and cost-effective form of transport; hence, it is very important for the economic development of any country. Easy availability and cost-saving are some factors that go in favor of road transport [1]. Every country makes considerable investment for developing its transportation system. Transportations involve many infrastructure elements. Among them, bridges perform a very crucial role in the transportation system. [2] The transport department should maintain the bridges in a proper state to avoid degradation. The average age of the bridges in the United States is 42 years. Because most bridges are designed and built to operate for a minimum period of at least 50 years of design

life, (American Society of Civil Engineers (ASCE) 2017). This means most of the bridges were meant to be designed or constructed with a minimum lifespan of 50 years. More than 40% of the bridges have exceeded their 50-year design life, and huge investment in maintenance, repair, and rehabilitation efforts is required. The most recent estimate is that the domestic backlog of bridge restoration needs in the United States is about \$123 billion [2].

In India, Ministry of Road Transport and Highways (MoRTH) established Indian Bridge Management System (IBMS) in 2015 for condition surveys, inventorying bridges, identification of bridges that are critically distressed, and rehabilitation and reconstruction of all bridges. IBMS uses mobile bridge inspection units

(MBIU) and indigenous software to create an inventory of bridges. In India, The average age of bridges is 30 to 40 year. Where, most of the bridges were design to last at least 50 to 75 year. About 200+ bridges exceeded their 75 year life span (Indian Bridge Management System (IBMS)). It means that maintenance, repair, rehabilitation programs need significant investment. In Most recent budget the Ministry of Road transportation and Highways (MoRTH) allocated with approximately 2.70 lakh cr.

LITERATURE REVIEW

The comprehensive research evaluates the operational functioning of bridge inspections and systems in India and the United States. It highlights both the similarities and differences between these two nations' techniques, strategies, and challenges.

American bridge management agencies and funding

With the expansion of the interstate highway system, bridge construction in the USA grew rapidly during the 1950's and 1960s [Federal Highway Administration [5]. Till 1967, inspection and maintenance did not gain much importance until the Silver Bridge collapsed. The US government passed the Federal Highway Act of 1968 due to the wellknown failure of the Silver Bridge. As a result of the regulation, the FHWA created the National Bridge Inspection Standards (NBIS) in 1971. National regulations for bridge inspection techniques, frequency, personnel qualifications, inspection reports, and NBI were established by the NBIS and the American Association of State Highway and Transportation Officials [5], [6]. The FHWA funded the creation of the "Pontis" BMS in 1991.

Any bridge network agency can embrace the Pontis system since it was flexible. The Pontis system is applied for bridge management in more than 40 states with varying levels of adoption.

Even though the budget restorations procedures are different in different states, the state bridges are partially financed through local and federal funding obtained from gasoline taxes among other sources of funding including bridge tolls. Most of the bridges situated in rural areas or outside the federal interstate highway system, most states appropriate a percentage of their general budgets for the maintenance of most bridges. The Highway Bridge Replacement and Rehabilitation Program of 1978 is the program that emerged from the origin of the Special Bridge Replacement Program of 1970, under which federal money was provided as aid to the state governments.

Inspection data for bridges will be obtained from the state and local governments to decide on the need and disburse funds for HBRRP. 80 percent of all the initiatives that are appropriately reported in NBIS methodology are given federal funds. Federal funds usage is regulated in every state uniquely [5].

Table 1 Bridge Infrastructure Particulars

Country	Total structures	Total length
USA	6,17,000+	6,586,610 km
India	1,73,000+	6,617,100 km

(Source: www.irc.com, www.dot.gov.com)

Indian bridge management agencies and funding

The Indian government, through the Ministry, set up the Indian Bridge Management System (IBMS) to effectively and comprehensively evaluate the condition of bridges and other structures within the National Highway Network. Mobile Bridge Inspection Units, together with locally developed software, are employed in carrying out comprehensive inventories and condition surveys. As of the available information, the IBMS have taken an inventory of more than 169,528 bridge structures and culverts. This inventory includes about 200 bridges older than 75 years, showing the age and possible vulnerability of some of the infrastructure.

One of the important roles played by the IBMS is to highlight critically distressed bridges that require special attention. The system has identified 147 such bridges in need of rehabilitation or reconstruction. Surprisingly, out of the bridges evaluated, 37 were reported in good condition and therefore show some positive impacts in the maintenance strategies implemented on certain components of the system.

Table 2: Features of India and US BMS

National	Name	Bridge details		Breakdown model	Cost information
		Bridge context	Bridge security		
U.S	PONTIS	Y	Y	Y	Y
INDIA	IBMS	Y	N/A	N/A	Y

The table shows the features of India's IBMS with the PONTIS Bridge Management System (BMS) in the United States. Additionally, both systems offer bridge security, context, and details. In opposition to IBMS, PONTIS offers extra features like cost information and

a breakdown model. That shows that PONTIS presents a more comprehensive approach to bridge management, including financial planning and predictive repair. IBMS, on the other hand, is a simple but efficient design that just provides basic bridge information and security. This signature subject shows again how the US and India handle their respective infrastructures separately with regard to of priorities and resource allocation.

BRIDGE INSPECTION METHODOLOGY

Methodology Follow for this experiment, thoroughly study all bridge inspection manuals provided by the government agencies of India and the United States of America and compare the different bridge inspection techniques in both countries in terms of the standard procedures, bridge inspector qualification, the latest bridge management system, and crack maintenance strategies.

American Inspection reference manual

The American and bridge inspection practices can be investigated by examining the representative bridge inspection reference manuals. The U.S. Bridge inspection materials chosen for examination are the 'FHWA Bridge Inspector's Reference Manual' distributed by the United States. Department of Transportation and the National Highway Institute (FHWA) and the AASHTO Manual for Bridge Evaluation, 2nd edition [7].

Indian Inspection reference manual

The Indian government official bodies i.e Indian Road Congress, (IRC) & Ministry of Road Transport & Highways (MoRTH) Provides the various bridge inspection standards to inspect the bridges. IRC SP: 35 provides the guidelines for regular inspection and timely maintenance, it aims to ensure the safety of bridge users. [5]. IRC SP 18RC: SP: 18 offered guidance on inspecting and maintaining highway bridges. This manual aimed to establish consistent inspection methods, reporting formats, and record management for effective bridge upkeep [4]. However, contemporary bridge maintenance practices are likely detailed in more recent IRC publications.

BRIDGE INSPECTION FREQUENCY AND CATEGORY

The FHWA manual classifies inspection into five levels: initial, routine, damage, in depth, and special, according to NBIS requirements. The regular inspections are planned to be carried out in less than every two years. According to

FHWA [5], underwater inspections fall under the in depth inspections category. Similar information is contained in the AASHTO manual, which shown in the Table 3 divides inspections into seven categories: initial, routine, damage, in-depth, fracture critical, underwater, and special. After construction or a change of ownership, initial inspections are the first one necessary to create a baseline or record. Regular inspections, which are carried out in every two years, are well recorded examinations of a bridge that meet NBIS standards. Damage inspections address emergency load restrictions or bridge closure caused by human and environmental activity. Comprehensive inspections find defects that are difficult to find with standard inspections and may call for specialized knowledge such as NDT or material testing. Steel fracture critical members are monitored through fracture critical inspections in order to assess the risk of fracture due to brittle failure.

Table 3: Details Bridge Inspection frequency

Comparison content	AASHTO	IRC
Inspection categories	7	7
Maximum periodic inspection frequency (months)	24	24

Bridge inspections in India are mostly classified according to frequency of inspection instead of strict "levels" and are further divided into routine inspection, in which the inspection is carried out every year; detailed inspection, which involves inspection of all parts with further studies being carried out if required; and special inspections, which are only done at specific events or dealt with specific complaints, using further advanced types of investigations. The goal of these inspections, as directed in IRC publications, is to provide enough information to set priorities for the repairs and ensure the continued safety of bridges. Condition is further useful for the health monitoring and management of bridges.

Inspection recording and reporting

As for the American system, a record shall be maintained of inventory, inspection, condition, and load rating; complete record of construction plans, maintenance, and technical specifications of the structure, including all subsequent changes to it [5]. The FHWA manual "Recording and Coding Guide for Structure Inventory and Assessment of the Country's Bridges, should be used by the inspectors as a tool in recording the crucial structural elements' conditions. BMS of the United States utilizes FHWA code, and all states are expected to maintain appropriate record

and data in appropriate format, although methods applied vary [6]. As mentioned in the AASHTO Guide.

In the Indian Bridge Inspection Manual, they provide the guidelines related to the storage of information related to all data from the construction of bridges to the regular inspection of the bridges in the Indian Bridge Management System. With different categories of the inspection, i.e., routine inspection, special inspection, as shown in the table The IBMS database consists of various modules designed for effective bridge management. The Reporting Module is responsible for generating reports and features a Ranking Sub Module to help prioritize actions. The Historical Database Module keeps records of past activities and links to the Specific M&R Action Selection Sub Module for customized maintenance, as well as the Life Cycle Costing Sub Module for analysing costs throughout an asset's lifespan. The Project Level Interface Module facilitates project-level operations and connects to the Optimization Sub Module to ensure efficient resource allocation. Finally, the Maintenance Module is dedicated to carrying out maintenance tasks and links to the Network Level M&R Selection Module for comprehensive maintenance planning across the system, ensuring optimal management of bridge assets.

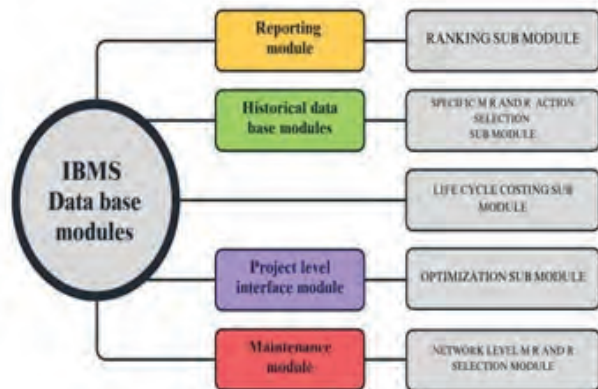


Fig 1: IBMS Data base module

(Source: Author)

Bridge inspector qualification

Training for the inspection team leaders of NBIS and the leaders of the inspection program is available in American manuals[8]. An inspection program manager is to be either a registered professional engineer or a graduate of the comprehensive bridge inspection course of FHWA and must have at least ten years of experience in bridge inspection.

Even though the requirements are less strict, a lead of an inspection team typically should have been certified under FHWA training, received accredited certification, and gained general bridge inspection experience [6]. In Indian scenario different grades officers are appointed as per the designation and experience as given in below table. No. 4

Table 4: Details Bridge Inspector Designation in U. S.

Qualification Area	Details
Education	Preferred: Bachelor's degree in civil/structural engineering.
Training	- FHWA-approved course,
Experience	Team Member: 2 years of inspection experience or relevant education/training. - Team Leader: PE license or 5 years of inspection experience.
Certification	Professional Engineer (PE) license often required for team leaders.
Continuing Education	Refresher training every 5 years.

Table 5 showing an obvious gap between management, leadership, and actual technical responsibilities, the table shows the roles and responsibilities of the various positions involved in bridge inspections in India.

Table 5: Details Bridge Inspector Designation and Duty In India

Staff Position	Responsibilities
Chief Bridge Engineer (CBE)	Ensures the compliance of bridge inspection operations with standards)
Deputy Chief Bridge Engineer (AE)	Responsible for assisting the chief engineer in managing the inspection program Supervises regional or zonal bridge inspection practices
Bridge Inspection Engineer (BIE)	Leads the onsite inspection process also conducts structural evaluations of bridges Prepares detailed inspection reports, including damage assessment.
Junior Engineer (JE)	Maintains record book of expenses and supports various inspection teams Assists in drafting reports and conduct minor repairs if needed.

Bridge inspection Detailing

It is also noted that visual inspection is referred to in American manuals of inspecting bridge components Substructures, superstructures, decks, approaches, waterways, and culverts. The FHWA manual describes how general inspection should be carried out, while the AASHTO manual describes what parts of a bridge should be inspected and how critical fractural parts should be inspected [6]. The FHWA manual gives detailed examples of structural and material deficiencies and defects that should be reported during inspection, including detailed photographs.

Inspection technology

Material field testing and non-destructive testing are covered in the AASHTO and FHWA manuals that provide guidelines for the same. The AASHTO manual offers tables of the effectiveness of NDT techniques to specific defects and American Society for Materials and Testing standards used for material study. Among the NDT techniques available in the AASHTO manual, acoustic, ultrasonic, magnetic, electrical, nuclear, thermograph, radar, radiography, and dye penetration are included. The FHWA suggested effective material inspection methods and nondestructive tests. Some of the common NDT methods explained under different parts are accelerometer testing, vibration, ultrasonic testing, and infrared testing.

It is also noted that visual inspection is referred to in American manuals of inspecting bridge components and materials that encompasses concrete, structural steel, timber, masonry, and other types of substructures, superstructures, decks, approaches, waterways, and culverts. The FHWA manual describes how general inspection should be carried out, while the AASHTO manual describes what parts of a bridge should be inspected and how critical fractural parts should be inspected.[5] The FHWA manual gives detailed examples of structural and material deficiencies and defects that should be reported during inspection, including detailed photographs.

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Material field testing and non-destructive testing are covered in the AASHTO and FHWA manuals that provide guidelines for the same. The AASHTO manual offers tables of the effectiveness of NDT techniques to specific defects and American Society for Materials and Testing standards

used for material study. Among the NDT techniques available in the AASHTO manual, acoustic, ultrasonic, magnetic, electrical, nuclear, thermograph, radar, radiography, and dye penetration are included.[7] The FHWA suggested effective material inspection methods and non-destructive tests. Some of the common NDT methods explained under different parts are accelerometer testing, vibration, ultrasonic testing, and infrared testing.

Load Rating

One of the major objectives of bridge inspections is to determine both preliminary and extreme case modifications that affect load capacity ratings. Load capacity ratings are normally established only once and are reassessed only in the event of a significant bridge. The FHWA guidebook uses AASHTO coding standards to find the usable live load capacity. Every bridge member has a load rating, and the critical members determine the posted rating. AASHTO uses the procedure that combines the acceptable stress/load factor rating with the new load and resistance factor rating (LRFR) procedures to determine inventory and operational load rating levels [7]. Gives the formula that is applied in determining the LRFR load rating. This is the formula for allowable stress and load factor ratings. [6]. C represents the sum of the nominal member resistance factors, condition, system, and Load and Resistance Factor Design (LRFD); DC stands for the dead load effect, and represents the LRFD load factor for structural parts. P represents load permanence from other than dead loads.

Crack limitation

Although the objective size limitation is absent, the two American guidelines have plenty of material in crack identification and evaluation. Both the structural design codes under the FHWA and AASHTO utilized limiting states on cracking[8]. BMSs rely on crack data to estimate deterioration and model propagation. Because they relate the susceptibility of rebar to water and other structural damage, crack widths are significant [7]. Cracks are generally classified by the AASHTO structural element standards. Beyond deteriorating low ratings of bridges in general, cracks degrade the ratings of specific bridge elements, which can be decisive when aggregated in a number of state processed rating schemes. In the United States, Severe cracking in concrete may justify partially damaged, close-up or special bridge inspections. The FHWA defines crack size for pre stressed and reinforced concrete.[6] As shown In Below Table 6.

Table 6: FHWA crack width definitions (mm) [6]

Crack Type	Reinforced Concrete	Pre Stressed Concrete
Hairline	< 1.6	< 0.1
Narrow	1.6 < < 3.2	0.1 < < 0.23
Medium	3.2 < < 4.8	0.23 < < 0.76
Wide	> 4.8	> 0.76

In India, the guidelines for assessing crack widths during bridge inspections are outlined in the Indian Roads Congress (IRC) codes, particularly IRC:SP:35 and IRC:112 (Code of Practice for Concrete Road Bridges). These codes specify the permissible crack widths for different exposure conditions and structural components to maintain durability and safety. The specification according to the IRC Given in Table 7.

Table 7: IRC crack width details

Parameter	Reinforced Concrete (RC)	Prestressed Concrete (PSC)
Mild	≤ 0.3 mm	Cracks not permitted
Moderate	≤ 0.3 mm	Cracks not permitted
Severe	≤ 0.2 mm	Cracks not permitted
Extreme	≤ 0.1 mm	Cracks not permitted

Bridge Rating System

The particulars, and areas of focus of the bridge inspection rating systems in the US and India differ strongly, indicating different approaches to infrastructure management. According to the National Bridge Inspection Standards (NBIS) in the United States, condition ratings are ranked from 0 to 9, with 0 denoting failure and 9 representing good condition. Various structural elements, such as decks, superstructures, and substructures, are assessed at routine, fracture-critical, and underwater inspections. Ensuring serviceability, load-carrying capacity, and public safety remain the top priority lists.

The Indian Roads Congress (IRC) codes, such as IRC:SP:35, which classify bridges into five conditions Very Good, Good, Fair, Poor, and Very Poor—are the guidelines that India's system adheres. In India, the focus of inspections is on detecting visible need, protecting structural safety, and rating durability in diverse environmental circumstances. When necessary, nondestructive testing is employed in

conjunction with manual and visual methods for these examinations.

India tends to use a more qualitative approach, whereas the U.S. system focuses mainly on quantitative. While India's system is adapted to its diverse climatic and infrastructure setting, the U.S. approach offers the advantages of consistency and innovative technology.

NOVEL TECHNOLOGY FOR BRIDGE INSPECTION

Accuracy and precision in bridge inspection are crucial for modern Bridge Management System to provide reliable and accurate information. While visual inspection data is regularly utilized by the U.S. & India. While data automation collectors can help address some of the problem in India, a significant amount of uncertainty from human observations stays the same. New methods, such as structural health monitoring (SHM) and non-destructive testing (NDT) techniques, are all implemented in the both countries. Some of new technologies are currently practicing by both the countries, Listed below.

- i) a Drones :- Drone or unmanned aerial vehicles(UAV), are used to give thermal data and high-quality pictures in locations that are difficult to reach. They increase safety and significantly reduce inspection time.
- ii) LiDAR:- This technology enables it possible to develop 3D models of bridges in order to identify structural concerns such as alignment and deformation.
- iii) Acoustic Emission Testing (AET): Offers early failure detection by using sound wave analysis to continuously monitor stress and cracks.
- iv) Digital twin Technology: Digital twin technology, offers the bridge in virtually simulated in real time for performance simulation, predictive maintenance, and regular inspection.
- v) Thermal Imaging: Uses infrared cameras to identify invisible cracks, moisture attack, and material deterioration. These technologies minimize the necessity for manual methods and significantly boost the quality of inspections. In Indian scenario some investigations has shown that India need enhanced inspection techniques.

DISCUSSION

For the purposes of to evaluate a possible benefit of using enhanced bridge inspection techniques, the present

study analyzes the American and Indian BMSs and Manuals. Also BMS practice was introduced, but in a simplified form. Since various techniques use to meet the requirements and philosophy of bridge management, further research must be conducted. The progressive supervision of more than a million bridges shows that both the American and Indian bridge management programs, which started about ten years earlier, have grown into reputable agencies with the ability to monitor bridges. The American and Indian inspection programs involve comprehensive information on the documentation needed to be recorded bridge inspections. The scope of India's and America's reporting and recording procedures is similar. Typical SHM monitoring contains focused data on the functionality of a single bridge; different methods, such as LiDaR technology, may measure the deflection, under clearance, and structural element damage for multiple bridges. Periodic inspection seems more suitable for conventional highway bridges, whereas continuous SHM is most suited for essential structures' health monitoring, such as long-span bridges. NDT and SHM procedures can work together to improve bridge inventory management overall while closely monitoring key components. Because of this, some emerging technologies, such as LiDaR processing, are an excellent method to increase the implementation of SHM systems.

CONCLUSION

This paper concludes that the bridge management practices in America and India are quite similar in terms of development and scale, allowing both countries to benefit from advancements in bridge management technology. The IBMS possesses the ability to simulate the productiveness of US technology. India could potentially adopt America's

advancements in bridge inspection and management efforts. In consideration of the results presented, it is suggested that Indian organizations recognize and adopt international bridge inspection technology for the advancement in IBMS.

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Life Cycle Cost Methodologies for Sustainable Concrete: A Comprehensive Analysis

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ABSTRACT

Concrete is used in greater number than any other building material in the world, but it additionally causes a lot of pollution, most notably through carbon dioxide emissions. Life Cycle Assessment (LCA) is a method used to assess the environmental effects of various concrete mixes, starting from getting raw materials to their removal at the end of their use. This paper provides a thorough review of LCA methods used for different types of concrete, such as Ordinary Portland Cement (OPC) concrete, mixed cement concrete, geopolymers concrete, and recycled aggregate concrete. It looks at their impact on the climate, especially greenhouse gas emissions, energy use, and resource depletion. The study also highlights emerging sustainable alternatives and their feasibility in large-scale construction projects. Furthermore, the paper discusses technological advancements, regulatory frameworks, and industrial best practices in sustainable concrete production. The findings emphasize the importance of adopting eco-friendly concrete formulations to reduce environmental impacts while maintaining structural integrity and performance standards.

KEYWORDS : *Life cycle cost analysis, Concrete mix design, Environmental footprints LCA methods of CM.*

INTRODUCTION

The Life Cycle Assessment (LCA) serves as an organised structure to examine the adverse environmental effects tied to a product or process into the duration of its life, from initial creation to final disposal. This is crucial for organisations to make informed decisions that minimise environmental impact and improve sustainability practices. The analysis of the environmental impacts of a product or process, from resource use to disposal, is known as life cycle assessment (LCA)[1]. Using this approach facilitates comparisons among different alternatives. LCA can highlight areas for improvement by looking at the entire life cycle of the product and examining how sustainability practices can be incorporated into any step of its manufacturing. Life cycle cost analysis is a tool to help in financial modelling of concrete pavement, that

includes a description of life cycle total costs and traffic intensities at which concrete pavement can be competitive [2]. It does not provide a definitive answer but rather assists the process of deciding. Additionally, competition, environmental concern, and economics could affect the decision of pavement selection [4]. Environmental impact is another consideration for pavement decision matrix for lifecycle cost analysis as these considerations allow us to analyse pavement types and lifecycle cost analysis. It may also identify areas where investing in innovation and technology can benefit both the environment and overall success of project. The use of recycled materials can impact life cycle costs by providing significant economic savings. An economic impact analysis showed that using recycled materials in highway construction resulted in total system wide economic savings of \$62.5 million, with estimated unit cost savings in 2013 for recycled materials

[3]. The true economic impact of using recycled materials depends on various factors and pricing comparisons with virgin materials [6]. Life cycle assessment (LCA) can be utilized to examine the environmental implications of various concrete mix designs, including traditional concrete. Mix design parameters, like the ratio of cement, aggregates, and water, are vital in determining the environmental implications of concrete production. [4] Research has established that conventional concrete mix designs, which extensively use Portland cement, have profound environmental implications due to high Carbon emission and depletion of resources in choosing types of pavement, giving an overview of total life cycle costs and traffic levels at which concrete pavement would be worth considering[6]¹.

It does not provide a definitive response but assists in decision-making. Other variables such as competition, environment, and economy may also affect pavement choice [4]. Life cycle cost analysis can also assist in establishing the environmental implication of various types of pavement, enabling more informed decision-making that factors in sustainability along with cost-effectiveness. It can also help identify areas where investments in technology and innovation will yield long-term benefits both to the in selecting pavement types, providing an overview of total costs during the life cycle and traffic levels at which concrete pavement could be considered. It does not give an absolute answer but helps in decision-making. Other factors like competition, environmental concerns, and economic factors may also influence pavement selection [7]. Life cycle cost analysis can also help in determining the environmental impact of different pavement types, allowing for more informed decision-making that considers sustainability alongside cost-effectiveness. Additionally, it can highlight areas where investments in innovation and technology could lead to long-term benefits for both the environment and overall project success [8].

Objectives

- i) Identifying opportunities for improvement in the concrete production process to minimize environmental impacts.
- ii) Identifying opportunities for improvement in the concrete production process to minimize environmental impacts.

LITERATURE REVIEW

LCA concrete mix design includes three mix designs that incorporate varying percentages of recycled aggregates to assess their environmental impact.[2] The literature review will also examine previous studies on concrete production processes to identify areas for improvement in sustainability practices.[4] The improvement of a more sustainable concrete mix design for subsequent construction endeavours is an ultimate goal of this work. Every mix design might develop concrete with equal mechanical durability and performance qualities [6]. GGBS and FA are byproducts; emissions from steel or renewable energy sources have no bearing on concrete manufacturing. Overall, the study shows that sustainable options for concrete mixtures are being looked into, but there are still problems with cost and availability [9][8]. that must be concluded before these sustainable practices methods may be effectively deployed to the construction sector. To get over those barriers towards greater adoption of sustainable concrete mixes, further research and cooperation between academics and experts in the field are required. of several replacements. Solving the issues of sustainable concrete mixtures' cost and availability is critical for the complete implementation of these eco-friendly methods in the building industry. Further research and collaboration between industry professionals and researchers are necessary to overcome these challenges and promote the widespread adoption of alternative materials. By working together, the construction industry can make significant strides in reducing CO2 emissions and creating more sustainable building practices for the future. [11] While cost and availability may initially pose challenges, investing in sustainable concrete mixtures can lead to long-term cost savings and benefits for the environment. Collaborative efforts between industry professionals and researchers can help find innovative solutions to address these issues and accelerate the adoption of alternative materials in construction. Environmental impacts of concrete production.

Different methodologies used in LCA include strategic planning for environmental strategy development, comparison of regional scenarios, identification of environmental improvement opportunities, product and process optimization, and creating frameworks for environmental audits.[18] Some examples include using LCA to compare scenarios for using excess bagasse in sugarcane production, analysing environmental benefits of different power plant feed options, and assessing life

cycle GHG emissions of electricity generation chains. Integration of LCA methodologies with optimization techniques is also being explored [13]. These methods can help organizations make informed decisions on how to reduce their environmental impact and improve sustainability [12]. By combining LCA with optimization techniques, companies can identify the most effective strategies for achieving their environmental goals. [7]

METHODOLOGY

The approach to LCA concrete mix design involves evaluating the ecological consequences of a concrete mix across its full life cycle, starting from the extraction of raw materials to the final disposal stage. The objective of LCA is to identify possible environmental effects and offer a comprehensive insight into the environmental footprint linked to a concrete mix. [2] [14]. Through the examination of elements like energy usage, emissions, and resource depletion throughout the entire life cycle of concrete mixes, organizations may identify specific areas that require expansion. This allows for the development of more sustainable concrete mixes that align with environmental objectives.

Selection of concrete mixtures for analysis and testing is a crucial step in this process

“The selection of concrete mixtures for analysis and testing is a crucial step in the process of designing geopolymer concrete. The methodology proposed in [14] aims to simplify the design process by emphasizing key principles, optimizing material selection, mixture proportions, and testing protocols. It combines the ACI 211 standards with certain oxide molar ratios to make a clear and consistent framework for designing geopolymer concrete mixes. Factors like alkali activation solutions and curing conditions are optimized to ensure practical applicability and cost-effectiveness. While the water content in geopolymer concrete mixtures is critical for achieving a balance between workability and strength, the curing process involves heat curing at 60–80°C for 24–48 hours. It is essential to conduct laboratory tests and trials to fine-tune the mix design for specific agro waste materials used[15]. The factors that influence concrete mixture selection include the water/cement ratio and density, which are found to be the most influential for producing sustainable concrete quality. Other factors, such as the ratio of fine aggregate to cement, the ratio of fine aggregate to total aggregate, cement type, types of aggregates, and characteristics of concrete, also play a role in determining

the overall quality of concrete [14]. The Department of Energy (DOE) method was found to be more suitable for sustainable concrete quality management, with a high potential for designing high-quality Concrete mixtures [16], [17].

Calculation of environmental impacts using LCA tools

“The SENSE tool is a web-based tool that allows for the calculation of environmental impacts of food products, integrating key environmental performance indicators and a common LCA framework for the food industry. It aims to provide a simplified way to calculate environmental impact for food products and create an Environmental Identification Document (EID) to communicate sustainability information. The tool has been validated against complete LCA studies for juice and beef and dairy chains, showing differences below 10% for various impact categories. [18][19]. This tool can help food companies make more informed decisions regarding the environmental impact of their products and identify areas for improvement. By providing a standardized framework for assessing environmental impacts, the SENSE tool promotes transparency and accountability in the food industry. It also allows companies to compare their performance with industry benchmarks and best practices.

RESULTS AND DISCUSSION

The impact of mix design parameters on the environmental effects of producing concrete and reinforced concrete buildings was examined through a life cycle assessment (LCA) and carbon footprint analysis. Cement was found to be the primary contributor to environmental impacts, accounting for approximately 90% of the carbon footprint. Sand, gravel, and admixtures also had significant impacts on LCA results. Mix design parameters play a crucial role in reducing the carbon footprint of reinforced concrete buildings” [14][9]. Concrete mixtures containing slag aggregate as fine aggregates or bottom ash aggregate as coarse aggregates have lower environmental implications than concrete containing natural aggregate. Geopolymer concrete has significantly lower global warming indicators than other types of concrete. The environmental impact of concrete mix design varies greatly, with different types of concrete having distinct global warming potentials. High-performance concrete (HPC) has a lower environmental impact than conventional concrete. Reactive powder concrete (RFC) emits less greenhouse gases and consumes less energy than ordinary concrete. Using fly ash and limestone powder in concrete can help to prevent global

warming. Certain concrete combinations can reduce CO₂ emissions in comparison to standard concrete.”es of concrete having distinct global warming potentials. High-performance concrete (HPC) has a lower environmental impact than conventional concrete. Reactive powder concrete (RFC) emits less greenhouse gases and consumes less energy than ordinary concrete. Using fly ash and limestone powder in concrete can help to prevent global warming. Certain concrete combinations can reduce 2 % of CO₂ emission in comparison to standard concrete. [14].

Key factors influencing LCA results related to concrete mix design include the availability and cost of alternative materials like GGBS and FA, which can impact their use in concrete production. Optimum mix designs for reducing CO₂ emissions may not always be the cheapest option, deterring the industry from exploring sustainable alternatives. The use of GGBS and FA has shown potential for reducing CO₂ emissions, but proper evaluation of concrete’s environmental impact is crucial for developing ‘green’ concretes [16]. Transportation-related impacts for concrete are important, with production impacts outweighing transportation impacts significantly. High-performance concrete (HPC) has shown reductions in global warming potential, eutrophication, acidification, and ozone depletion, emphasizing the importance of design choices in reducing environmental impacts.

For construction projects, and the need for further research on sustainable concrete materials and practices is essential for promoting environmentally friendly construction practices. Additionally, incorporating life cycle assessment tools into decision-making processes can help in identifying the most sustainable options for concrete production and use.

Discussion

In general, the study highlighted the importance of providing environmental considerations into consideration when working on construction projects and indicated potential benefits of making sustainable design decisions. In the future, it is essential for researchers and industry professionals to work together to come up with new ways to minimise the environmental effects of concrete production and construction techniques.

Mix 2 (CEM II/B-V) and Mix 3 (CEM III/B) were found to be able to be produced in a more environmentally friendly way in a study that compared the environmental impact of three different concrete mixes. GGBS was recommended

as the optimal choice for reducing CO₂ emissions, while FA also showed sustainability benefits compared to PC. However, some impact categories like COD, P, AOX, metals, and pesticides did not show significant improvements in Mix 2 and Mix 3 [9].

- Recommendations for improving the environmental sustainability of concrete production To improve the environmental sustainability of concrete production, it is recommended to focus on cement conservation, water conservation, and concrete durability. By minimizing Portland cement use, using water more efficiently, and enhancing concrete durability, the environmental impact of the concrete industry can be reduced [20] [21].

CONCLUSIONS

The key findings related to LCA of concrete mix design include the recommendation to use GGBS as the optimal addition for reducing CO₂ emissions, with FA also improving sustainability compared to PC. The study compared three various concrete mix designs: CEM I, CEM II/B-V, and CEM III/B, focusing on carbon dioxide emissions.

This research can inform policymakers and industry professionals on the benefits of utilizing alternative concrete mix designs to mitigate CO₂ emissions and improve sustainability in the construction industry. By incorporating GGBS and FA into concrete mix designs, companies can make significant strides towards reducing their environmental impact and meeting sustainability goals

More studies in the future could look at how to make concrete mixtures less harmful to the environment by using more SCMs, such as GGBS & FA This could lead to a significant decrease in carbon emissions and improve sustainability in concrete production Additionally, exploring the performance, cost implications, and availability of SCMs in concrete mix designs could be valuable for future research [7].

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A Review on Construction Technology-Traditional Construction Method and 3D Printing Technology

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ABSTRACT

In recent years some significant advancements have been witnessed by the construction industry, with traditional methods being increasingly challenged by innovative technologies such as 3D printing. This study presents a comparative analysis between traditional construction techniques and the emerging 3D printing technology regarding efficiency, cost-effectiveness, material usage, and sustainability. Traditional construction methods, which rely on manual labor and conventional machinery, are contrasted with the additive manufacturing process in 3D printing, which involves layer-by-layer material deposition to build structures. The paper examines various aspects, including construction time, quality control, labor requirements, environmental impact, and the potential for large-scale adoption. This study culminates that while 3D printing is not a complete replacement for traditional methods, it offers substantial advantages for specific applications and has the advantage of changing the future of construction.

KEYWORDS : *Technology of 3D printing, Cost, Time.*

INTRODUCTION

Hideo Kodama in 1981, studied and published printed solid model manufacturing, the start point of 3D printing technology has been accurately improved and used as a tool for designers, scientists, and engineers [4]. It helps the user to create three-dimensional which creates objects by adding layers through the process of additive manufacturing. Additionally, construction cost is less. In the industry, 3D printing has been gaining enormous attention from all corners of the global sector of construction. This research paper focuses on the key areas considering the 3D printer's role in the industry of construction. Though the development was in the 80s, it was not useful at that time due to its high cost. By 2000, it became more user-friendly, enabling designs to be created on computers.

The cost of comparison decreased significantly since for the 3D house the plastic and waste are used to form

concrete since it became affordable for a various model, designs, and more [6]. With the change in techniques of additive manufacturing also termed 3D printing, and the technological advancements in today's world, the work of automation in the industry of construction seems to be more realistic. Some users believe that 3D printing in concrete is not only just an advanced technology but can also revolutionize the industry of construction and has the potential to revolutionize the construction industry. Using this technology can reduce the time and cost and the construction can be carried out in more remote areas of various locations for flexible design. Additionally, according to a recent study it offers new sustainable benefits that are not seen in typical construction [1]. The process of converting a real object into an object model in a computer environment is simply 3D printing, by building them layer by layer using the required raw materials [1]. When the 3D printer was first invented, it was seen as a complex as well as an expensive technology. However, as

the years passed, it has become one of the most important advancements in the industry [1]. Initially, it was a very expensive as well as complicated technology. Over time, in everyday life, this latest technology began to appear, with printers becoming widely adopted across various industries. Significant progress has been made in fields like aerospace, medicine, and automotive. Open-source systems have played a key role in these advancements, and the new products of prototyping, and 3D printing creative applications in the different sectors are now accessible to the community [5]. The enhancement of printing materials and 3D technology has become a key objective for many companies worldwide across various industry domains [5]

EXAMPLES OF 3D PRINTING

Canal house (Amsterdam)

In 2014, a Dutch architecture firm decided to design and build a house by printing its parts with a giant 3D printer. The project called the 3D Print Canal House, is the first of its kind in Europe to be fully realized utilizing 3D printing technology. Situated in Amsterdam, the project is expected to be completed within three years. The architect's goal is to prove that on-site 3D printing of the house components not only cuts down on waste generated during the building process but also significantly lowers transportation costs by eliminating the need to transport materials to the site. The mobility of the printer is considered a major advantage, as it can be easily transported worldwide, this capability could potentially eliminate the costs associated with transporting and storing materials at the construction site. The timeline of the projects was designed for the study of printing technologies and the development of appropriate materials. The site remains open to the public and accessible also after the project's finalization, with the primary goal being to explore and communicate [5].

It begins with creating models in a 3D program on a computer, which is then changed to the required format. The biodegradable thermoplastic material is heated to a liquid state, enabling the printer's nozzle to lay it down in layers, with each layer added on top of the last. The main challenge in this process is creating a material that is flexible enough for layer formation, adhesive enough for layers to fuse, and rigid enough to retain the component's shape once finished [5].

WinSun Company building

A company from China is developing a 3D printable material similar to concrete. 3D-printed houses were

built in the year 2014 by them. This approach consists of printing building components as ready-made sections, which are then pieced together at the construction site. The printer, with dimensions of 40x10x6m, pushes the material i.e. motor through a nozzle, creating it layer by layer. The walls are reinforced diagonally and include a hollow design, which works as an insulating layer. The walls are equipped with windows and doors. Once the roof is set, the final touches are completed, and the buildings are ready. Each building is estimated to cost \$4,800 [5]. WinSun system uses large 3D printers, some of which can print entire structures, including walls, floors, and foundations. The company has garnered global attention for its capability to produce prefabricated, 3D-printed construction [5].



Fig. 1 (a) Win Sun's first 3D-printed home (2014) [5]



(b) A structure built using 3D printing [5].

TYPES OF 3D PRINTING

Several types with some being more ideal for construction purposes than others.

1. Concrete 3D Printing: Contour Crafting (CC) technology, invented in the USA, employs the extrusion method to deposit two layers of cement-bases material, creating a vertical concrete framework,

the print head is equipped with trowel-like fins to smooth the surfaces as the material is laid down. Once the framework is completed, concrete is poured manually to a depth of 13 cm. After an hour, a second batch of concrete is added, with a one-hour delay that helps to regulate the lateral pressure by allowing the material to partially cure.



Fig. 2. A concrete wall structure formed by a CC machine, incorporating specially designed reinforcement ties inserted by hand between the layers.

2. Concrete Printing: Concrete printing technology, pioneered by a team in the United Kingdom, adopts an extrusion-based technique that resembles CC technology [3]. This process is extrusion-based, with the nozzle dispensing material as it moves along a predetermined route in a continuous flow. In real-time construction, three primary types of concrete printers are in use, each having a printing nozzle and an uninterrupted material supply. The height of the gantry is fixed and the cranes are adjustable in the vertical direction. The dimensions of the robots are fixed, though this makes scaling up tricky, they can work in all operational directions enabling seamless and full in-situ printing. [1]



Fig. 3. A full-scale bench was created using concrete printing, incorporating post-tensioned reinforcement and functional voids

3. D shape printing: It involves stacking layers of powder, with adhesive added at predetermined locations. At specific places, the binder is injected with the help of a nozzle. The loose powder can be removed when the process of hardening is completed and the model which is hardened can be separated. Techniques like inkjet printing and laminated object printing, which fall under the category of binder jetting, are used in the construction. [1].



Fig. 4. D shape printing

4. 3D Printed Housing (Modular Systems): Some companies use 3D printing to create pre-constructed building modules that are printed off-site and later assembled at the building site. This system uses concrete, cement, or hybrid composite materials and is ideal for affordable housing, disaster relief shelters, and rapid construction in areas with housing shortages [1].

GRAPH COMPARING BREAKEVEN ANALYSIS

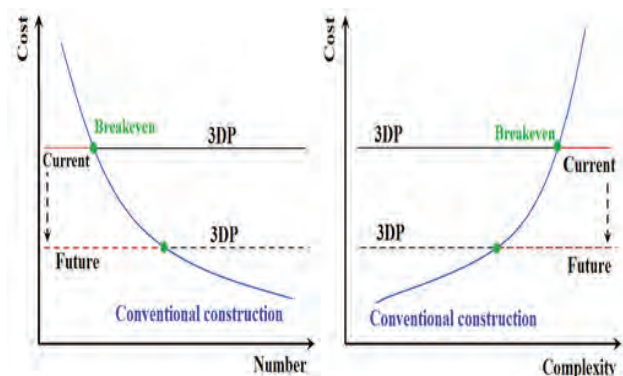


Fig. 5. Graph comparing 3DP processes. Image reproduced from [8]

PROCESS

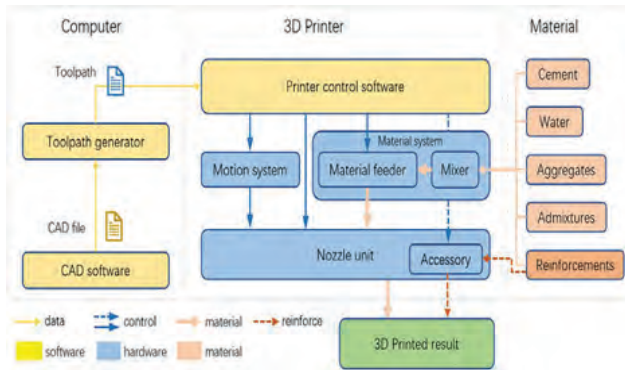


Fig. 6. Process of 3D printing [8]

THE INFLUENCE ON TIME, COST, AND ENVIRONMENTAL FACTORS OF CONVENTIONAL CONSTRUCTION METHODS

Currently, the construction industry is experiencing rapid growth due to higher living standards, increased demand for infrastructure, evolving consumption patterns, and the natural rise in the population. This development has been a significant factor in the rise of waste creation.

- I. Consequences of building materials: Building materials have a substantial effect on the environment. Many of these materials are produced in unsustainable ways, with factories manufacturing them often emitting harmful CO₂ emissions. Additionally, transportation contributes to the environmental impact, as materials not locally produced are regularly delivered from distant places, whether from other regions or overseas, which negatively affects air quality. Furthermore, the removal and utilization of raw materials for building purposes add a considerable environmental impact [1].
- II. Construction and demolition waste: Demolition and renovation activities in construction yield a significant amount of waste, such as concrete, glass, metal, plastic, concrete, wood, brick, etc. This waste not only pollutes the air and land, but the transport needed to remove it also creates a significant environmental footprint [1].

CONVENTIONAL METHOD VS 3D PRINTING

The construction industry faces an urgent need for

decarbonization. 3D printing or additive manufacturing, offers a viable approach to reduce energy requirements, cut water wastage, and lower carbon emissions. 3D printing in construction is an advanced technology that forms three-dimensional objects by layering materials one on top of another. Recently, the industry has advanced from using polymers and steel to incorporating concrete, offering potential applications in construction engineering. Anecdotal evidence suggests that these technologies can shorten production time, reduce waste, and decrease labor costs considerably [1]. The main barriers to the commercialization of 3D printing in construction are the absence of unified building codes, high investment costs, performance limitations, and constraints in architectural designs. Concrete prototypes were printed for testing in the study, and a comparison with conventionally made concrete was carried out to analyze performance criteria, cost advantage, and lifecycle assessments. [1].

Advantages

- 3D-printing can also make expensive shapes that are impossible to make with the traditional method of construction.
- NASA uses 3D printing technology for the colonies on Mars.
- 3D printing enhances efficiency by automating production, resulting in reduced construction time and faster project turnarounds.

LIMITATIONS:

- Some regions have limited access to the necessary raw materials required for 3D printing, which could affect the availability and cost of materials for large-scale construction.
- The process of 3D printing, especially when using large machines, can be energy intensive, which could reduce its sustainability benefits if not offset by renewable energy sources.
- Due to their considerable size, these printers make on-site storage problematic.

CONCLUSION

The 3D printing technology is advanced and has very high expectations and hopes from the future generation for the construction of bungalows, houses, as well as high-rise buildings. The demand for this is increasing rapidly and can be considered as the future of construction. Demand

for this technology is increasing and in the next few years, each construction industry will be needed to adapt this technology to stay competitive in the business world.

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A Review on Fast Charging Station for Electric Vehicle

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ABSTRACT

With Increasing Demand of EV's There Is a Need a Sufficient Charging Infrastructure to Handle These Vehicle. We examine the infrastructure of fast charging stations in this paper. Self-Regulated Algorithm (SRA) for EVs and Grid-Regulated Algorithm (GRA) for GICs are both included in the proposed Smart Charging Algorithm (SCA), which fully coordinates the Grid's source/load characteristics. When power fluctuations cause a change in DC bus voltage, the Self-Regulated Algorithm does not go beyond the predetermined threshold. Calculate each EV's charging power using its SOC feedback, which validates the fast charging station's power.

KEYWORDS : *Smart charging algorithm, Fast charging station, Solid-state transformers (SST).*

INTRODUCTION

Electric vehicles and hybrid electric vehicles are being promoted globally in an effort to decrease the use of fossil fuel resources and address the growing concern about climate change brought on by carbon emissions. Along with lowering vehicle costs, the primary focus on the growing use of electric vehicles will assist to improve battery technology, driving range, and electric vehicle performance in addition to lowering carbon emissions and operating costs. In plug-in electric vehicle, the batteries will be charge from grid or by using separate clean energy sources. The effectiveness and layout of the Power Electronics Converter electric car charging station will have a significant impact.

Description of existing charging station

When it comes to electrical charging stations for electric vehicles, two primary kinds are available: conductive and non-conductive: AC and DC.

The electric vehicle charger is linked to the secondary side of a distribution transformer that converts medium voltage to low voltage [34], which serves as a common AC bus in AC charging systems.

DC fast-charging systems use a common AC/DC converter attached to the Medium Voltage (MV)-Low Voltage (LV) distribution transformer, in contrast to AC charging which uses onboard AC/DC converters.

An off-board AC/DC converter is connected to a common AC bus with a 400–480V rating in DC fast-charging systems. These power electronic converters supply the EV port with DC power, isolation, voltage control, power factor correction, and rectifications. There are several power conversion stages in the AC-bus architecture.

Extreme fast charging (XFC) Stations – The design and construction of charging infrastructure become more difficult and expensive as the number of charging stations rises. When you factor in the price of all the required electrical components such the transformer and feeder, the cost of installation of Extreme Fast Charging (XFC) stations can be extremely high. It is anticipated that EVs would present a huge new burden on the power circulation framework and present difficulties for the utility as demand increases and charging costs climb. The daily shift and rise in peak demand, overload of transformers and feeders, faster ageing of transformers, and increased power losses may all result from unmanaged EV charging. Additionally, the chargers are merely the power electronics interface,

which draws a steady amount of power. This could negatively influence the dependability of the conveyance framework, bringing about voltage lopsidedness and a decrease in power quality. Incorporating a few battery energy capacity frameworks and sustainable resources into XFC stations is one of the potential ways to lessen the power.

A SURVEY OF WORK DONE IN THE RESEARCH AREA AND NEED FOR MORE RESEARCH

By referring to the various literatures proposed by researchers, some of the problems and their benefits are identified and summarize as follows.

H. Tu, H. Feng [1] has presented, Uncontrolled EV charging can lead to a daily change in peak load and an increase in peak load, which can accelerate transformer ageing, cause overload in feeders and transformers, and increase power losses. Furthermore, the chargers are merely the power electronics interface, which pulls a steady amount of power. This could negatively impact the stability of the distribution system, resulting in voltage imbalance and a reduction in energy efficiency. To lessen the load on the power system and the amount of energy used to charge electric vehicles, one option is to incorporate battery energy storage devices and various renewable resources into XFC stations.

Md Ahsanul Hoque Rafi [2] the author has described, the application of three energy storage technologies: hydrogen, flywheels, and batteries. Consideration of hydrogen storage should be limited to situations when refilling fuel cell cars is also necessary, and exploration of flywheels should be limited to situations where energy storage can simultaneously provide high power grid services. In addition, batteries usually have the highest efficiency, lowest volume, and lowest cost.

In their proposal, Chen Lei and Cheng Qifu [3] Even without energy storage system (ESS) support for fast charging stations (FCS), the Smart Charging Algorithm (SCA) may optimise PV power production and grid interlinking converter (GIC) utilisation by completely coordinating the source/load characteristics of EVs and the grid. The GRAC for Grid Interlinking Converters (GICs) and the SRA for Electric Vehicles make up the Smart Charging Algorithm (SCA). If the Smart Charging Algorithm (SCA) is able to completely mobilise the power move of GICs and EVs in FCS, offsetting the power will

be capable discrepancies produced by EVs' irregular access and PV systems' intermittent operation. As a result, FCS power supply will be stable, and it will be possible to make good use of the EVs' dynamic load characteristics.

Vijay K. Sood and Gagandeep Sharma [4] To tackle the pertinent power quality concerns, we evaluate two popular bus topologies for grid-connected EVFCS: DC and AC. It is advised to use normal AC transport geographies and unipolar normal DC transport geographies for FCS. A two-level Voltage Source Converter (VSC) joins the EVFCS to the network by means of DC and AC transports in the two strategies.

A voltage source inverter that integrates photovoltaic (PV) and electric vehicle (EV) charging stations through a typical network associated ac-transport has an optimal set of control settings that have been suggested by Ahmed A.S. Mohamed, Ahmed [5]. Optimising the controller settings to lower the variation in the dc-transport voltage is accomplished by adjusting the dynamic power stream and the infused sounds to the network utilizing the Salp Multitude Calculation. Using particle swarm optimisation and system transfer functions, we compare the controller's performance to that of an ideal control architecture and study its behaviour under various severe disruptions from the producing and loading sides.

Gowthamraj Rajendran, Chockalingam Aravind Vaithilingam [6] has presented Power converters are essential parts of the design and operation of EV charging stations. Since state-of-the-art research makes it possible for EVs or idle batteries to serve as distributed energy sources, modern charging station technologies exhibit promise. Be cautious that the input current's music and power factors don't surpass as far as possible consistently. With regards to further developing power quality and unequivocally administering voltage levels during bidirectional power stream, serious areas of strength for action switch-mode power converters have progressed significantly.

Iyer Vishnu Mahadeva, Guler Srinivas [7] At an Extreme Fast Charging (XFC) station, several electric vehicles (EVs) may be charged at the same time. The galvanic isolation is accomplished using soft-switched solid state transformers (SST) based on dual active bridge (DAB), and the medium voltage (MV) grid is interfaced directly with a cascaded H-bridge (CHB) converter. Boost system efficiency and reduce installation and operational expenses.

Fareed Ahmad, Atif Iqbal [8] An overview and comparison of the various issue formulation strategies used by researchers to position EVCSs are given. Enhancement of operating parameters as well.

Srdjan Srdic and Srdjan Lukic [9] The author has talked about the design, key features, and state-of-the-art quick chargers. Furthermore, By connecting these chargers, fast-charging stations that function similarly to petrol stations can be created. A number of power supply strategies are described for these charging stations.

A control approach for fast charging stations (FCS) for plug-in electric vehicles (PEVs) that employ flywheel energy storage systems (FESS) has been proposed by Bo Sun and Francisco D. Freijedo [10]. The FESS's primary function is to ensure that the PEV battery's predetermined charging profile is maintained while the overhead power system receives a hysteresis-type active power auxiliary service.

Mostafa M. Mahfouz, M. R. Iravani [11] The researcher creates and assesses a control structure and system architecture that lessens the effects of electric vehicles (EVs). weak AC grid that houses a DC fast-charging station. Eigenvalue analyses of the charging station's dynamic models in the two modes are conveyed out in order to build the Local Controllers.

Yongmin Zhang, Pengcheng You, and Lin Cai [12] simulated the functioning of a double mode charging station as a fixing network with different servers and variable help rates, and afterward assessed the connection between the charging station's administration dropping rate and EV alternatives. The next step in reducing the number of uncharged electric vehicles is to establish a customer attrition minimisation challenge.

Finding out how big of a storage system a quick charging station needs is possible with the help of Soodeh Negarestani and Mahmud Fotuhi-Firuzabad [13]. The first step is to estimate the demand for PHEV charging at a station using PHEV characteristics and PHEV owners' driving habits. Next, in order to keep energy and storage costs down, the ideal size of the charging station's electrical storage system is calculated.

Xuebing Han, Languang Lu, and Shuoqi Wang [14] To make sure the DC micro grid runs reliably and independently, we suggest a new decentralised virtual-battery droop control system. This system is capable of balancing the state of charge (SOC) of the energy storage

system (ESS), dispatching electricity to the load, and maintaining bus voltage.

Kuo Yang and Ping Chen [15] EV users are particularly interested in charging schedules that yield the lowest charging costs because of the market's rapid development in EV adoption. Assuming daily EV data in real-world operations are predictable, this research proposes two global optimisation methods—one in light of hereditary calculations and the other on unique programming—to upgrade the charging plan at DC quick charging stations for electric vehicles to diminish charging costs.

Duan Ditao and Poursaleman Roza [16] This research suggests a PEV charging station that is connected to the dissemination framework as an extra part of the energy stockpiling framework, close by the batteries, diesel motor, and sunlight powered chargers. Additionally, three speed levels—fast, medium, and slow—are considered in the design and optimisation of the charging facilities.

Liu Xiaoyi and Feng Tianyuan [17] This paper proposes a way to set up energy-storage systems (ESSs) for electric vehicle (EV) rapid charging stations that takes use of the ESSs's ability to quickly modify by considering charging load characteristics and variations in wind power. By adjusting its design, the ESS may lessen the load on fast charging stations while simultaneously making the distribution network that supports them more economically efficient.

(Wu Xiaomei, Feng Qijin, Bai Chenchen) [18] Considering the bus distribution and operation networks, this article suggests a model for the electric transport travel framework's position arranging of quick charging stations. The objective of the concept is to lower the overall cost of constructing, running, and maintaining charging stations, as well as the expenses associated with transportation to and from them and power outages at specific bus terminals.

Baojun Sun [19] has proposed the optimal design for energy storage, solar, and wind systems in fast EV charging stations (FEVCS-WPE), which determines the power scheduling strategy and component capacity configuration. In order to dynamically modify charging expectations based on power pricing at the moment of use, a demand response-based The first step is to develop a model for recreating the heap of electric vehicle charging lines. Secondly, a multi-objective optimisation model is suggested, taking into account the system architecture, with the minimal goals of power cost and pollutant emissions.

Appel, Jeffrey, and Shekar Visvanathan In [20], Even though San Diego has satisfactory chargers to match its flow interest for electric vehicle charging, the paper guarantees that the general population charging appropriation network is now underutilised and disorganised. To make the charging network more accessible and available in San Diego, it is suggested that the best model be used and that the charging site need be set. By doing this, the waste that arises from the charging infrastructure's bad design will be reduced, and each charger's consumption rate will be increased.

Zheng Xue-qui, Yao Yi-Ping Chang [21] has suggested using V2G to establish two charging and discharging modes. In accordance with the TOU pricing mode, improper usage of the vehicle's charging and discharging modes has not been permitted [36]. Consequently, customers do not pay to park, but the cost to utilise it has increased.

Md Ahsanul Hoque Rafi, and Jennifer Bauman [22] Has offers a thorough analysis of DCFC stations with energy storage, including topics such as system topologies, power electronic converters suitable for every choice, inspiration, and the three energy stockpiling arrangements (battery, flywheel, and hydrogen). Cost, volume, and efficiency may be measured for small, medium, and large DCFC stations using Simulink models for each option [34].

Chang Kuo, Pinggen Chen [23] Charging schedules based on GA and DP were proposed in this article as a means to lower the cost of charging electric vehicles at DCFCs. Over the course of thirteen days, extensive data on electric vehicle operations and baseline charging schedules were collected using a Nissan Leaf EV equipped with a 62 kWh battery pack.

Participants: Chaowanan Jamroen, Issarachai Ngamroo, and Sanchai Dechanupaprittha [24] Looking at the issue from both the utility's and the owner's points of view, this study examined how supplementary frequency stabilisation for electric vehicle charging may be affected by uncertainties in the charging process.

Lu Wang ,Zian Qin ,Tim Slangen, Pavol Bauer [25] has looked at the most recent EV fast charging standards and technologies, which amply demonstrate the advancements achieved in the direction of UFC. We also go at the PQ problems that FCSs and DCFCs cause in great detail. Specifically, it reveals that FCSs and DCFCs mostly cause PQ issues due to their poor voltage profiles and high harmonic emission and amplification.

Xingzhen Bai, Zidong Wang, and Lei Zou [26] detail the dynamic demand prediction that is the basis of the EV charging station arranging trouble. The unique interest forecasting method for electric vehicle charging was created by studying EV users' travel habits and taking into account the connection between EV charging requirements and individual driving routines. There is also a new multi-objective planning model that takes the unwavering quality of the power framework, the expense of charging, and the eccentricities of EV travel into account.

Several requests for rapid charging stations in urban areas and along highways were identified in an analysis of the economic viability of stationary storage systems by Simon Funkea, Patrick Jochemb, and Sabrina Riedc [27]. Fast charging stations installed along highways need a lot of electricity to continue to charge periods short, which causes gigantic burden pinnacles of around 10 MW? Alternately, charging stations in urban areas might have less power since drivers might utilize that time for other things, like doing shorter errands. While the costs of connecting to the grid may be lower in a metropolitan setting, they are substantial in a highway scenario.

Hassani, S.A., Khaleghi, A., and Hooshmand, F. (2015) [28] in For the issue of charging station placement in metropolitan settings, a two-stage stochastic programming model and a heuristic arrangement in view of drinking sprees disintegration were presented. Compared to direct solution utilising MIP solvers, the computational results from several instances show that the proposed technique can rapidly find a close ideal arrangement. Researchers should look on creating a reliable meta-heuristic approach to handle increasingly complicated instances of the problem in the future.

Lau Lang, Xuebing Han, Minggao Ouyang, and Shuoqi Wang [29] Specifically, this study suggests a novel decentralised main control approach for DC microgrids that combine PV-ESSGrid. On the basis of the Virtual-battery hung control of the ESS, transport flagging control empowers the decentralized fundamental control. The reference voltage and virtual opposition of the virtual-battery hung control, a versatile hang control, not set in stone when fluctuating properties of the ESS. An online measurable, pragmatic, and boundary based way to deal with ESS hang control and a variable mode-exchanging voltage of composed One possible application of the virtual-battery paradigm is the development of bus-signaling control approaches.

In an effort to reduce the amount of time that automobiles sit idle while charging for dynamic ridesharing services, Tai-Yu Ma and Simin Xie [30] have suggested a new approach for assigning charging stations. Optimal placement of several fast-charging stations subject to unpredictable customer demand is achieved by the integration of the suggested internet charging strategy into a bi-level enhancement reproduction model. Because the charging infrastructure is complex and automobiles' charging needs are unpredictable, the time it takes for a car to reach a charging station may be thought of as a multi-server queuing system. By using an effective charge management strategy, transportation network businesses may optimise charging and reduce the overall charging durations of daily operations.

An EVCS that use a multiterminal VSC DC-connect geography has been concentrated by Francisco de Paula García-López and Manuel Barragán-Villarejo [31] to moderate the effect of EV fast charging on the conveyance framework. By incorporating numerous DC quick chargers with the conventional power electronic structure blocks — a VSC and a DC/DC converter — the recommended EVSC method shortens the overall time needed to charge daily operations.

Duan Ditao and Poursoleiman Roza [32] This article introduced an EVCS that could accommodate several types of energy sources. The BESS unit, charging station, network reinforcement, and charging facilities were all constructed with a focus on minimising expenses. The best way to run the BESS unit and the diesel generators was calculated using this model. The standards referenced above were all carried out utilizing a stochastic questionable parametric model. Applying the TLBO approach addressed this optimisation problem.

The effect of quick charging stations on the low-and high-request sounds of three-phase power amounts has been studied by B. Basta and W.G. Morsi [33]. Following the illustration of the mathematical description of the apparent power and effective distortion in three-phase systems, the consonant twisting is estimated at both the low-request and high-request symphonious bending levels. Research shows that chargers from various manufacturers may lead to varying degrees of consonant current mutilations at the framework level. These mutilations influence both low-request and high-request sounds, with the latter having the potential to approach 18%.

Research by M. A. H. Rafi and J. Bauman [34] on DCFC

stations with energy limit, including topographies, power electronic converters, motivation, and a total reproduction examination for different charging situations. Personally associated with the latest cutting edge innovation, the review consolidates both scholarly exploration and genuine energy stockpiling projects that are now taking place worldwide.

You, P., and Zhang, Y., and Cai, L. [35] We are aiming to establish an ideal valuing framework for the charging station so the pace of administration drops is minimised. The operation is first formulated.

analyse the relationship between the electric vehicle options and the pace at which the double mode charging station's administration drops, and consider it a lining network with numerous servers and different help rates.

The creators Zheng and Yao [36] have advanced Interfacing enormous EVs to the miniature network would cause a plenty of issues. Taking into account vehicle-to-lattice (V2G) innovation, this study created two EV charging and releasing burden modes. Both the movement propensity based dislocated charging and releasing mode and the hour of-purpose (TOU) cost based efficient charging and releasing mode were tried utilizing the Monte Carlo technique. It was proposed to improve the limit of a sun based charging station using V2G in two distinct charging and discharging modes.

CONCLUSION

- Research in this paradigm will go in the following directions in the future:
 1. The design of FCS will provide a different direction by taking into account many elements like charging time, installation cost, smooth operation, etc.
 2. An examination of quick charging stations and how they affect power quality.

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A Review of Power Quality Challenges Associated with Electric Vehicle Charging Stations

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ABSTRACT

Now a day, governments are migrating to electric vehicle (EVs), over traditional fossil-fuel vehicles due to the growing concern over environmental issues and global warming. As a result of this change, there are now a lot more EVs that can connect to the electrical grid. However, the integration of these vehicles introduces several challenges to the power grid, particularly related to interactions of vehicle-to-grid (V2G) and grid-to-vehicle (G2V) mode of operations. One of the primary concerns is the impact on power quality within electrical grids affected by the presence of these vehicles. This paper aims to explore and analyze the challenges that electric vehicles pose to electrical networks. In this context, the present and future state of EVs are discussed. The problems that occur when EVs are connected to the electrical grid are also covered in the study.

KEYWORDS : *EV charging station, Electric distribution system, Electric vehicle (EV), Power quality (PQ).*

INTRODUCTION

The global marketing of hybrid electric vehicles (HEVs) and electric vehicles (EVs) has promoted in response to the growing worries about the use of fossil fuels which results in climate change brought on by carbon emissions. In addition to lowering greenhouse gas emissions and carbon emissions, the widespread usage of EVs promotes the substitution of renewable energy sources for fossil fuels. The power electronic converters, also known as the vehicle charger, acts as a bridge between the distribution feeder and plug-in electric vehicles, which charge vehicles batteries through the electrical grid.

Power electronics devices are increasingly integrated into the electric grid. These devices, which manage the conversion and control of electrical power, enable advancements in power generation and consumption technologies. In particular, power electronics have made it easier to integrate renewable energy sources and create new kinds of loads. However, these devices can lead to some challenges, such as increased voltage and current distortion due to their nonlinearity, which can cause issues when excessive. New sources of harmonic distortion,

such as compact fluorescent lamps (CFLs), LED lamps, distributed photovoltaic (PV) systems, adjustable speed-drive appliances and electric vehicle chargers, are becoming more common in the distribution grid, with their penetration likely to increase. While various devices can generate high-order frequencies, are becoming more common in the distribution grid, with their penetration likely to increase. While various devices can generate high-order frequencies, this study primarily focuses on their impact on the distribution feeder.

Large energy storage devices are on-board that can be recharged from the grid are a feature of electric vehicles, such as battery driven electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). High recharging capabilities, up to several hundred kW for ultra-fast charging, are necessary to replenish the batteries in these cars, which typically have energy capacity of several tens of kWh. A conversion of power from alternating current (AC) sources to direct current (DC) is required because the batteries run on DC. This conversion is achieved through power-electronic rectifiers, which can be located within the vehicle or at dedicated EV charging stations. These

rectifiers can contribute to current harmonic distortions, potentially affecting the grid's stability. The growing use of EVs and other power-electronic-based devices has raised concerns about their effects on the distribution network, creating new challenges for the electric grid. Understanding the impact of these devices is becoming increasingly important to ensure continuous and reliable power distribution.

Power quality refers to maintaining a power system's rated voltage and current in a near-sinusoidal waveform at the proper magnitude and frequency. Any deviation from this quality can reduce system efficiency. Typically, power quality control focuses on voltage, as it is generally easier to manage than current. Parameters used to define power quality include service continuity, variations of voltage, voltage transients, current transients and harmonic content (for AC systems). Both suppliers and customers may be burdened by needless energy losses and financial expenses brought on by poor power quality. Studying how power quality problems affect distribution feeders and the electric grid as a whole is essential because voltage and frequency instability can interfere with power flow through the grid.

This paper reviews the power quality challenges faced by distribution networks due to the introduction of new loads, such as electric vehicles and their chargers.

Also, it organized in different section such as I. Introduction, II. Summary of PQ in modern & traditional electrical networks, III. PQ with EV's in conventional electrical networks, IV. Positive impacts of V2G (vehicle to grid) scheme, V. Discussion, VI. Conclusion.

SUMMARY OF PQ IN CONVENTIONAL & MODERN ELECTRICAL SYSTEMS

Examination of PQ Problems, Their Root Causes, and its Impact: This following section offers a comprehensive review of the key power quality (PQ) issues faced by modern power systems, examining their causes, effects, and classifications. It highlights various factors that contribute to deteriorate PQ and how they affect the reliability and performance of the system. The classification of these issues, as shown in Fig. 1 [1-4], includes transient-related PQ problems categorized by peak magnitude, frequency components and duration of signal. These issues are further divided into short-duration and long-duration problems depends on change in their magnitude and duration. harmonic spectrum analysis and total harmonic distortion (THD) are key tools used to identify waveform

distortions, while intermittency serves as an effective metric for detecting voltage fluctuations [1-4]. To enhance understanding, the most common phenomena and their causes and impacts are summarized in Table 1.

PQ Problems in Conventional Electrical Systems: Any non-linear loads dominate the system are typically some elements contributing to the related power quality challenges encountered by traditional power systems, which are characterized by large centralized generation units, overhead transmission and distribution infrastructure, and passive consumer behavior, are identified [1]. Overheating of motors, saturation of transformer, capacitor overloading, system resonance, mal-operation of protection devices, changes in light intensity, loss in generation, damage to the generator and turbine shafts and even health issues like headaches and being uncomfortable can all result from PQ issues [1,2].

PQ Issues in Modern Electrical Systems: The increase in integration of distributed energy resources (DERs) which promoted the penetration of power electronic devices, and the evolution of electrical loads provide a variety of power quality (PQ) difficulties for modern power systems. As a result of advancements like electronic appliances, LED lights, adjustable speed drives (ASDs), inverter based renewable energy sources has increases non-linearity from both generation as well as customer demand side. PQ is also impacted by emerging technologies such as power line communications, HVDC lines, and the growing trend of replacing overhead wires with underground connections. Concerns about PQ are growing as the deployment of smart home technology and electrified vehicles (EVs) is accelerated by the global drive to decrease environmental harm. These changes create new challenges for system operators, highlighting the need for further research into the causes, effects, and potential economic and environmental consequences in modern power systems due to PQ issues.

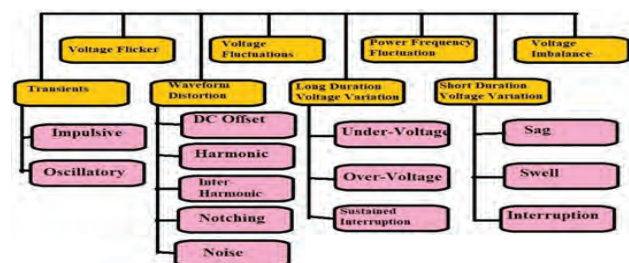


Fig. 1 PQ issues classification

Over the past few decades, the widespread usage of DERs has led to a noticeable increase in the use of power

electronics-based interfaces. In contemporary power systems, power electronic devices are more widely distributed than in classical power systems, where they functioned as stiff non-linear loads [3]. In addition to the growth of DERs, the worldwide push to cut pollution emissions has accelerated the uptake of EVs and other electrified cars. Therefore, it can be claimed that this shift has been influenced by both advancements in generation technology and modifications to the characteristics of electrical loads.

More non-linearity is now present in both the generating and demand sides of modern power systems. PQ issues are made worse by the proliferation of electronic smart home gadgets, ASDs, and LED lighting. The conventional layout of power networks is also changing due to the incorporation of HVDC lines, improved communications of power transmission line, and the transition from overhead transmission system to underground connections.

Research into the nature, causes as well as techno-economic outcomes of PQ problems is now more important than ever because of the significant economic losses brought on by these problems [2, 3]. The new effects resulting from contemporary system improvements need more research, even though certain effects can be deduced from traditional system degradations.

PQ WITH EV'S IN CONVENTIONAL ELECTRICAL NETWORKS

Power quality (PQ) can be greatly affected by the charging habits of electric vehicles (EVs), which are becoming more and more integrated into traditional electrical networks. Harmonics, phase imbalance, power losses, and voltage variations are typical PQ problems. This section examines how EVs affect these PQ issues and offers some possible fixes [1].

Voltage Profile: Electric vehicle (EV) charging has the potential to affect electrical networks' voltage levels, resulting in problems including voltage drops and fluctuations. These effects, particularly how EV availability and behaviour affects system voltage, have been studied. For example, a Monte Carlo simulation is one of the approach used to identify the impact of unpredictable EV charging availability on voltage stability [5]. The type of network, quantity of EVs, and a charging features are some of the variables that affect the effect level. While some studies indicate that the influence on voltage is negligible at low EV penetration levels [7], others demonstrate that at larger penetration levels, like 50%, voltage variations

above allowable limits [6]. Furthermore, one study [8] discovered that even a small number of fast-charging EVs might lead to network voltage violations.

Numerous approaches have been put forth and evaluated in order to address these voltage issues. To lessen voltage variations, conventional methods such as installing tap changers and ideal capacitor banks are frequently used [9, 10]. An another approach is used to enhance the voltage profile of the network by controlling EV charging. For instance, a smart load management system that synchronizes EV charging was investigated in a study in [11]. It proved that the grid's voltage levels could be successfully stabilized by synchronizing the schedule and pricing of EV charging.

Furthermore, sophisticated EV charger control techniques can aid in voltage regulation. Reactive power control is one of the approach to maintain voltage levels in grid, while control of active power modifies the EV charging process. So, as a part of a separate active and reactive power control method is used to control voltage as well as EV charging process [8]. In this regard, it has been demonstrated that a bidirectional DC fast-charging station, as modelled in [8], controls voltage by means of controlling the reactive power into the system. A three-phase off-board EV charger that helps control the network voltage and maintain a steady DC-link voltage without interfering with charging was created in another study [12]. As EV usage rises, these management systems provide distribution and transmission service providers with workable ways to efficiently regulate voltage profiles.

In conclusion, managing EV charging is crucial for ensuring voltage stability in power networks. By employing advanced control techniques and coordination strategies such as real power and reactive power management, utilities can mitigate the voltage challenges associated with the rise in EV use.

Unbalance of Phase: The use of single-phase EV charging technique in electrical grids causes the system to operate in unbalanced mode, increasing power losses and causing voltage limit breaches. In a study published in [14], focused on assessment of an impacts of EV charging on voltage unbalance in a LV distribution network by using the Monte Carlo simulation approach, taking into account the uncertainties in EV connection points and charging rates. According to the results, EVs raised the voltage unbalance factor at distribution feeder end but had no

effect on the voltage balance at the feeder's start [14].

There are several approaches that have been put out to deal with voltage imbalance. Along with other instruments like energy storage devices, D-STATCOM and capacitor bank helps in enhancement of quality of power in terms of voltage fluctuations and unbalance, voltage regulators are frequently used in order to reduce voltage unbalance index within a network [9, 10]. Reconfiguration of phases is another strategy to lessen the imbalance brought on by EVs. The economic advantages of reconfiguration of phases reduces the effects of EVs on voltage unbalance in LV distribution networks were examined in research in [13]. Additionally, the findings from [15] demonstrated that phase reconfiguration combined with time-of-use tariffs can successfully reduce the imbalance implications of EVs. Furthermore, phase unbalance can be addressed with the best possible control over charging and discharging of EV. It is feasible to balance the system voltage by choosing the right phases (R, Y, or B) and EV charging or discharging location and timing, as well as by modifying charging power rates. According to the study in [16], the grid's voltage imbalance factor is greatly reduced when EV charging and discharging are managed cooperatively. This cooperation contributes to the electrical system's overall stability.

Harmonic: Both voltage and current distortion can be injected into electrical distribution network by the rectifiers in EV chargers [17]. According to a study in [18], the effect of harmonic distortion on network power quality (PQ) is negligible when EV penetration is low and charging rates are sluggish. Significant harmonic distortions in voltage and current, however, may arise as the number of EVs and charging speeds rise [23, 19]. Additional research in [20] showed that EVs' erratic charging habits may result in voltage harmonic levels that are higher than acceptable bounds.

There are several tried-and-true methods for minimizing or completely removing the harmonics that EV chargers produce. These include techniques like powerfactor modification in EV chargers or the installation of shunt active power filters in charging stations [22, 23]. However, shunt active power filters can sometimes amplify current harmonics, which could exacerbate the issue [21]. According to some study, EVs themselves can be used as harmonic compensators by either injecting or absorbing harmonic currents into or out of the network [24].

Additionally, by participating in reactive and harmonic power ancillary service markets, EVs can help the grid in this regard [24].

Table 1. Characterization of Most Frequent PQ Issue [1-4]

PQ Issue	Characteristics	Causes	Effects
Voltage Sag	Magnitude: (10-90%) Vrms, Frequency: power frequency Duration: 0.5 cycles to 1 min	Connection of heavy loads, EV's, starting of motor, Single line-to-ground fault	Maloperation of protection and control circuitry, Loss of generation
Voltage Swell	Magnitude: (>110%) Vrms, Frequency: power frequency Duration: 1 cycle to few second	Switching of Capacitor banks, Large loads, Faults, EV's, Non-regulated transformers	Malfunction of protection, Stress on home appliances and computers
Short Interruptions	Duration: few milliseconds to 2 seconds	Temporary faults	Loss of generation, Malfunction of fire alarms
Long Interruptions	Duration: greater than 2 seconds	Faults, Protection equipment failure	Loss of generation
Voltage Imbalance	Imbalance in three phase voltage amplitude and/or phase angles	Single-phasing, Unbalanced Loading	Heating of Induction Motors
Harmonics	Frequency: integer multiple of power frequency	Non-linear loads, adjustable speed drives, LEDs, Arc furnaces, EV's, Inverter based DGs	deteriorate power factor, Electromagnetic interference

According to a paper in [25], significant impacts on the current's total harmonic distortion (THD) can still occur at modest EV penetration levels. Furthermore, common harmonic frequencies that coincide with those generated by EVs may be contributed by harmonic current sources such as wind generators. The system's harmonic control is made even more difficult by this interaction.

Power Loss: Electric vehicle (EV) integration into the electrical grid has a substantial impact on power flow across the network, increasing power losses in different power system components. The high EV penetration

can significantly increase losses in distribution system, particularly when charging occurs unregulated, according to studies by [27, 28]. Furthermore, a study in [29] discovered that when a significant number of EVs are incorporated into the grid, distribution transformer losses might be tripled.

Coordination of EV charging and discharging has been proposed as a viable remedy to lessen the detrimental effect on power losses due to EV integration. For example, in [30], it is suggested that EVs be charged and discharged in residential areas in unison in order to avoid system losses and peak loads. Using a stochastic programming technique, another study [31] showed how to reduce power losses by using an optimal coordinated charging strategy. Effective EV load management can reduce power losses by as much as 10%, according to [28].

Other tactics have also been investigated, such as scheduling EV charging in real time. In low-voltage residential distribution systems, real-time scheduling of EV charging based on EV availability can assist reduce power losses or voltage drops, according to a paper [32]. Further lowering network power losses can be achieved by incorporating Distributed Generators (DGs) to meet EV charging demand [26]. EV charging can sometimes be fully powered by renewable energy sources, and optimal power loss reductions can be obtained by balancing the fluctuation of renewable energy supply with the stochastic nature of EV charging demand [33, 34].

Frequency: In order to keep the grid frequency within reasonable bounds, it is essential for electric power systems to continuously balance generation and load. Additional power generation is needed to maintain a steady grid frequency when a large EV charging is added to the system [35]. The system is made more uncertain by the EVs' arrival and departure times, which raises the possibility of demand-side swings [33]. Demand-Side Management programs or load curtailment can be used to help balance generation and consumption in order to overcome these issues.

In order to manage this balance and support grid stability, coordinated EV control can be very important [35]. Groups of EVs under collective ownership, known as EV aggregators, are also able to take part in the energy and auxiliary services markets. EVs are useful for grid support because they are more affordable than conventional energy storage devices and can ramp up more quickly than gas turbines [33]. The effect of EV integration on power

system quality has been the subject of much research, which has identified a number of problems and potential fixes. An overview of these difficulties is given in Table 2, which groups the problems pertaining to EV integration and how they affect power quality.

Table 2. PQ issues with the penetration of EV chargers

Challenges	Remarks
Voltage Fluctuation	•Minimal impact due to limited adoption of EVs [6] •Significant impact achieved with 50% adoption of EVs [8]. •few EVs equipped with fast EV charging technology have high impact [27].
Voltage Unbalance	•High impact as a result of large no. of EV single-phase charging [28].
Power Losses	•large no. of EVs and uncontrolled charging system have high impact [29, 36]. •High impact as a result of large no. of EV single-phase charging [28]. •Significant effect on power losses and distribution transformer rating with high penetration [18].
Harmonic	•Low impact due to low EV penetration and slow charging rate [20]. •High impact due to high EV penetration and fast charging rate [9]. •High impact due to random EV charging [10].

POSITIVE IMPACTS OF V2G (VEHICLE TO GRID) SCHEME

Apart from the difficulties associated with integrating electric vehicles (EVs), the Vehicle-to-Grid (V2G) idea offers plugged-in EVs a chance to communicate with the grid by returning excess electricity. This makes it possible for charging stations to contribute to the energy management of the grid and make money. Peak load reduction, spinning reserve provision, enhanced load management, voltage stabilization, decreased line losses, and frequency regulation support are some advantages of the V2G scheme [37].

DISCUSSION

The conclusions of the study are reviewed in this section. With an emphasis on factors including, power quality, peak load impact, voltage stability and transformer performance, Figure 1 contrasts several research on how EV charging stations affect the electrical grid. Although there isn't much research on how EV charging stations affect peak load, there is a growing amount of effort in

this field. The majority of studies concur that adding EV charging may worsen the grid's operating characteristics. However, given that the V2G system has potential benefits for grid management, it is crucial to acknowledge that its beneficial effects should not be disregarded.

Future studies may examine the following topics:

- a. Reliability Assessment: Assessing the impact of EV charging stations on grid reliability indices.
- b. Economic Analysis: Examining the financial losses incurred by utilities as a result of EV charging station integration.
- c. Impact Mitigation: Creating plans to use coordinated charging techniques to lessen the adverse effects of EV charging loads.

Future research can maximize the integration of electric vehicles (EVs) into power systems by examining these avenues, maximizing the advantages of EVs while reducing any potential drawbacks.

CONCLUSION

Devices based on power electronics are becoming a more essential component of contemporary electrical grids. The vehicle charger's power electronic converter serves as a conduit between the distribution network and the electric car. These gadgets are made to convert and control electricity, which makes it possible to include cutting-edge technology into the production and use of energy. New kinds of loads have been introduced as a result of power electronics, which has also opened the door for creative methods of producing electricity, especially when using renewable energy sources.

However, a number of power quality (PQ) problems are brought about by the broad use of these technologies, especially electric vehicles (EVs). Table 1 lists the most prevalent PQ obstacles and summarizes these problems, which might impact the grid's performance and stability. Conversely, Table 2 examines the particular difficulties associated with EV grid integration, especially in relation to their effect on PQ. As power electronics continue to transform the energy environment, overcoming these obstacles is crucial to preserving a dependable and effective power system.

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Cancer Chemotherapy Dosage Estimation Using Robust Controller for Non-linear Kernel-Based Error Function

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ABSTRACT

Chemotherapy remains to be one of the most important treatments for diseases like cancer. Determining the ideal drug injection rate during treatment has drawn a lot of interest lately due to controller-based approaches. To control drug dosage in this environment, this work suggests a unique, robust controller that efficiently estimates parameters. An Extended Kalman Filter (NEF-EKF) based on a Nonlinear Error Function and combined with an Improved Scaling Factor (ISF) is presented in this study. Unlike traditional methods, which calculate error using standard difference functions for updating the EKF, our prior work employed a nonlinear error function for this purpose. This study advances that approach by utilizing the nonlinear error function in a scaled environment for the updating process. Furthermore, the introduction of a scaling factor leverages historical error trends to enhance the update mechanism. Effectiveness of proposed controller for regulating effects of drug dosage on tumor, immune, along with normal cells is demonstrated by comparative performance evaluations, which also emphasize the higher accuracy of NEF-EKF-ISF in tumor cell estimation.

KEYWORDS : *CART chemotherapy, Drug dosage, Extended Kalman filter, Controller, Error function.*

INTRODUCTION

Cancer has increasingly become a devastating health challenge [1] [2] [3], necessitating advancements in diagnostic and therapeutic methods. Assessing the efficacy and feasibility of chemotherapy plans remains critical in improving treatment outcomes. Chemotherapy [4] [5] [6], a conventional approach to cancer treatment, is widely adopted in medical practice. Administering chemotherapy drugs effectively is recognized as a superior therapeutic strategy, attracting significant global attention. The integration of engineering science has played a vital role in this domain, leading to the development of numerous numerical models that analyze the effects and dosages of chemotherapeutic agents [7] [8] [9].

These methodologies have been extensively utilized to design and evaluate diverse drug control strategies [10] [11] [12]. Cost-effective, these “in silico trials” enable engineers as well as clinicians to evaluate efficacy of novel pharmacological drug dosing strategies.

Additionally, siRNAs, along with chemotherapy drugs [13] [14], are becoming more popular as a combination for treating cancer. Reducing damage to healthy cells and minimizing drug side effects are the primary objectives of two-dimensional models that incorporate siRNAs and chemotherapy drugs [15] [16]. However, repeated chemotherapy sessions [17] [18] often lead to severe adverse effects caused by chemotherapeutic agents, undermining treatment outcomes and contributing to diagnostic failures [19] [20] [21].

Kalman filtering techniques have become integral to estimating dynamic states, improving estimation accuracy, and enhancing temporal resolution, thereby enabling precise drug dosage assessment [22] [23] [24]. Despite their advantages, a significant challenge in applying Kalman filters lies in configuring the covariance matrices. To address this, the Extended Kalman Filter (EKF) is employed to enhance dynamic state estimation (DSE) accuracy. Moreover, EKF is effective in estimating

immune cell counts and adjusting drug dosages, thus regulating normal, immune, as well as tumor cells during chemotherapy [25].

Paper's main contributions are as follows:

1. A novel robust controller is introduced for the regulation of drug dosage in addition to parameter estimation.
2. A new NEF-EKF-ISF has been presented, employing a historical error function for updating processes suited to a nonlinear framework.
3. A scaling factor has been established to account for previous error improvements in updating mechanism.
4. Comparative assessments highlight the superiority of the suggested controller relative to traditional approaches, illustrating its influence on normal, immune, and tumor cells.

This paper is structured as follows: Part II examines related work. The nonlinear mathematical framework for chemotherapy is described in Section III. The robust adaptive control system's modeling is covered in Section IV. Improved Kalman filter with enhanced nonlinear kernel-based error function and scaling factor is described in Section V. Experimental data are displayed in Section VI, and conclusion is given in Section VII.

LITERATURE REVIEW

Table 1 summarizes key findings on cancer chemotherapy dosage systems from various studies. In [1], a Reinforcement Learning (RL) model was first presented, ensuring efficient treatment without necessitating prior understanding of system dynamics. However, there is a need to emphasize adaptive RL models. Partial Differential Equations (PDEs) were utilized in [2], proving to be more effective by reducing tumor volume, though combined therapy considerations are necessary. In [3], a gradient algorithm was used, which resulted in rapid convergence and shorter computing times. It doesn't, however, encompass penalty terms. Association between SMA and p62 expressions was also evaluated using Spearman rank correlation method in [4], which proved to be accurate but necessitated additional research on the interactions between cancer cells as well as CAF.

Steepest Descent Method, used in [5], improved cost functions and allow for personalized drug injection; however, it ought to concentrate more on closed-loop control. Multi-Objective Algorithms (MAs) used in

[6] minimized tumor cells and enhanced sensitivity, though realistic diagnostics via implementation remain unaddressed. Ridge regression in [7] reduced costs and effort but requires further exploration of logical parameters. Lastly, a PID controller proposed in [8] reduced processing time and enhanced accuracy, but its control design process demands further attention.

Table 1. Features and Challenges of Cancer Chemotherapy Dosage Models Using Various Techniques

Author [citation]	Features
Regina et al.[1]	Ensure effective treatment. Does not require system dynamics knowledge.
Lai and Avner[2]	Highly effective in reducing tumor volume.
	Provides fast convergence. Wu and Qiaodan[3] Reduces computational time.
Liang et al.[4]	Assesses SMA and p62 expression relationships. Offers a reliable approach.
Khalili and Ramin[5]	Optimizes cost function. Customizes drug injection.
Wang et al.[6]	Minimizes tumor cells. Enhances sensitivity.
Nazila and Lotfi [7]	Lowers costs. Reduces effort and time.
Sofiane et al.[8]"	Reduces processing time. Increases accuracy.

CHEMOTHERAPY: NON-LINEAR MATHEMATICAL FORMULATION

In present investigation, a robust nonlinear control method that manages parameter uncertainty effectively is presented. The performance of the system is examined by employing a minimal-order simplified chemotherapy model. This method takes into account how "immune cells, tumor cells, along with normal cells interact. Eq.(1)-(3) demonstrates nonlinear model where , and indicates count of immune, normal, and tumor cells at time , correspondingly.

$$\overrightarrow{ID} = st + \frac{\rho ID \cdot T}{\alpha + T} - q_1 ID \cdot T - t_1 ID - y_1 u_1 ID \quad (1)$$

$$\dot{T} = ra_1T(1 - c_1T) - q_2ID \cdot T - q_3TD - y_2u_2T \quad (2)$$

$$\dot{D} = ra_2D(1 - c_2D) - q_4TD - y_3u_3D \quad (3)$$

The control inputs under consideration are drug injections. Impact of chemotherapy drug is indicated by $u_1(n)$, $u_2(n)$, $u_3(n)$, respectively." The model assumes an immune cell type capable of reducing tumor size through kinetic interactions. It also includes immunity cells stimulated by tumor presence, including T-cells. Furthermore, it is considered that whole cell populations can be destroyed by chemotherapeutic drugs at varying rates.

Bone marrow, as well as lymph nodes, can develop constant sources for cells, as indicated in first term of Eq. (1). $\frac{\rho ID \cdot T}{T}$ demonstrates saturation function having positive constraints that include ρ as well as α along with this constraint, directly suggests that immune cells are stimulated by tumor cells. $q_1ID \cdot T$ indicates competition among immune as well as tumor cells that leads to immune cell loss. y_1u_1ID indicates immune cell loss due to injection of drugs, while t_1ID suggests that immune cells are destroyed at t_1 natural death rate.

"Eq. (2), $ra_1T(1 - c_1T)$ indicates enlargement of tumor cell population that is depicted as logistic term with t_1^{-1} utmost carrying capability as well as ra_1 growth rate. Conflicts between growth rate as well as death rate are described by logistic growth terms" [26]. $q_2ID \cdot T$ indicates competition between immune as well as tumor cells, which leads to tumor cell loss. Similarly, conflicts between tumor as well as normal cells are described by q_3TD which leads to tumor cells loss while y_2u_2R indicates tumor cell loss owing to drug injection.

In Eq.(3), normal cell population growth has been demonstrated by $ra_2D(1 - c_2D)$ as logistic model having growth rate and t_2^{-1} . Additionally, y_3u_3R indicates normal cell loss due to drug injection. q_4RD indicates conflicts between normal as well as tumor cells that lead to normal cell loss. Accordingly, y_1 , y_2 and y_3 denotes effect of chemotherapy on destroying cell population.

MODELING OF ROBUST ADAPTIVE CONTROL SYSTEM

A strong adaptive control framework for a third-order nonlinear model is described in this section. Controlling system states (immune, tumor, normal cells) toward their

corresponding optimal levels is the controller's main objective. For this, biological cell volumes (immune, tumor, normal) are measured about their optimal values, producing error signals that direct the suggested dosages of drugs.

Moreover, to design a robust system capable of addressing parameter uncertainties, system parameters are assessed and incorporated into control loop. Third-order tumor model described in Eq. (1), (2), and (3) is reformulated in Eq. (4) and subsequently reorganized into Eq. (5).

$$\begin{bmatrix} \dot{ID} \\ \dot{T} \\ \dot{D} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ \frac{ID \cdot T}{\alpha + T} & 0 & 0 \\ -ID \cdot T & 0 & 0 \\ 0 & T & 0 \\ 0 & T^2 & 0 \\ 0 & -T^2 & 0 \\ 0 & -ID & 0 \\ 0 & -TD & 0 \\ 0 & 0 & D \\ 0 & 0 & -D^2 \\ 0 & 0 & -TD \end{bmatrix} \begin{bmatrix} x \\ \rho \\ q_1 \\ t_1 \\ ra_1 \\ ra_1c_1 \\ q_2 \\ q_3 \\ ra_2 \\ ra_2c_2 \\ q_4 \end{bmatrix} - \begin{bmatrix} y_1IDu_1 \\ y_2Tu_2 \\ y_3Du_3 \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} = \begin{bmatrix} \frac{1}{T} & 0 & 0 \\ \frac{T}{\alpha + T} & 0 & 0 \\ -T & 0 & 0 \\ -1 & 0 & 0 \\ \frac{-ID}{ID} & 0 & 0 \\ 0 & 1 & 0 \\ 0 & -T & 0 \\ 0 & ID & 0 \\ 0 & -T & 0 \\ 0 & \frac{-T}{T} & 0 \\ 0 & 0 & 1 \\ 0 & 0 & -D \\ 0 & 0 & -T \\ 0 & 0 & \frac{-D}{D} \end{bmatrix} \begin{bmatrix} \frac{x}{y_1} \\ \frac{\rho}{y_1} \\ \frac{q_1}{y_1} \\ \frac{t_1}{y_1} \\ \frac{1}{y_1} \\ \frac{ra_1}{y_2} \\ \frac{ra_1c_1}{y_2} \\ \frac{q_2}{y_2} \\ \frac{q_3}{y_2} \\ \frac{1}{y_2} \\ \frac{ra_2}{y_3} \\ \frac{ra_2c_2}{y_3} \\ \frac{q_4}{y_3} \\ \frac{1}{y_3} \end{bmatrix} \quad (5)$$

Eq. (6) represents regression vectors. The parameter vectors are calculated as shown in Eq. (7), and constraints are replaced with estimated values to account for model uncertainties.

$$\begin{aligned} G_1 &= \begin{bmatrix} 1 & T & -T & -1 & -ID \\ ID & \alpha + T & & & ID \end{bmatrix} \\ G_2 &= \begin{bmatrix} 1 & -T & -ID & -D & -T \\ & & & & T \end{bmatrix} \\ G_3 &= \begin{bmatrix} 1 & -D & -T & -D \\ & & & D \end{bmatrix} \end{aligned} \quad (6)$$

$$\begin{aligned} \bar{\theta}_1 &= \left[\frac{\bar{st}}{\bar{y}_1} \quad \frac{\bar{\rho}}{\bar{y}_1} \quad \frac{\bar{q}_1}{\bar{y}_1} \quad \frac{\bar{t}_1}{\bar{y}_1} \quad \frac{1}{\bar{y}_1} \right]^T \\ \bar{\theta}_2 &= \left[\frac{\bar{ra}_1}{\bar{y}_2} \quad \frac{\bar{ra}_2 \bar{c}_2}{\bar{y}_2} \quad \frac{\bar{c}_2}{\bar{y}_2} \quad \frac{\bar{c}_3}{\bar{y}_2} \quad \frac{1}{\bar{y}_2} \right]^T \\ \bar{\theta}_3 &= \left[\frac{\bar{ra}_2}{\bar{y}_3} \quad \frac{\bar{ra}_2 \bar{c}_2}{\bar{y}_3} \quad \frac{\bar{c}_4}{\bar{y}_3} \quad \frac{1}{\bar{y}_3} \right]^T \end{aligned} \quad (7)$$

Consequently, to establish a stable system, the states (tumor, normal, immune cells) align with their respective optimal values, as expressed in Eq. (8). In this equation, the positive constants are represented by γ_1, γ_2 and γ_3 . ID_t and $\bar{ID}_t$ are optimal values and derivatives of immune cells. T_t and $\bar{T}_t$ represents optimal values of tumor cells along with their derivatives, D_t and $\bar{D}_t$ are desired values in addition to their derivatives of normal cells. Eq. (9) can be obtained by substituting Eq. (8) in Eq. (6).

$$\begin{aligned} \bar{ID} &= \bar{ID}_t - \gamma_1 (ID - ID_t) \\ \bar{T} &= \bar{T}_t - \gamma_2 (T - T_t) \\ \bar{D} &= \bar{D}_t - \gamma_3 (D - D_t) \end{aligned} \quad (8)$$

$$\begin{aligned} G_1(\bar{ID}_t - \gamma_1 (ID - ID_t), ID, D, T) &= \begin{bmatrix} 1 & T & -T & -1 & -\bar{ID}_t - \gamma_1 (ID - ID_t) \\ ID & \alpha + T & & & ID \end{bmatrix} \\ G_2(\bar{T}_t - \gamma_2 (T - T_t), ID, D, T) &= \begin{bmatrix} 1 & -T & -1 & -D & -\bar{T}_t - \gamma_2 (T - T_t) \\ & & & & T \end{bmatrix} \\ G_3(\bar{D}_t - \gamma_3 (D - D_t), ID, D, T) &= \begin{bmatrix} 1 & -D & -T & -D \\ & & & D \end{bmatrix} \end{aligned} \quad (9)$$

Control law in Eq.(10) is taken into consideration according to regressor form of system equation, in which $\bar{\theta}_1$, $\bar{\theta}_2$ and $\bar{\theta}_3$ represents assessing vector constraints. Adaptation law for examining vector parameters is indicated by Eq.(11), in which Γ_1 , Γ_2 and Γ_3 indicates symmetric positive definite constant measures. Error vectors of normal, immune, as well as tumor cells are indicated by $\bar{\bar{D}}$, $\bar{\bar{ID}}$ and $\bar{\bar{T}}$, respectively, as demonstrated in Eq.(12).

$$\begin{cases} u_1 = G_1 \bar{\theta}_1 \\ u_2 = G_2 \bar{\theta}_2 \\ u_3 = G_3 \bar{\theta}_3 \end{cases} \quad (10)$$

$$\begin{aligned} \bar{\bar{\theta}}_1 &= \bar{\bar{ID}} \cdot ID \cdot \Gamma_1 G_1^T \text{sign}(y_1) \\ \bar{\bar{\theta}}_2 &= \bar{\bar{T}} \cdot T \cdot \Gamma_2 G_2^T \text{sign}(y_2) \\ \bar{\bar{\theta}}_3 &= \bar{\bar{D}} \cdot D \cdot \Gamma_3 G_3^T \text{sign}(y_3) \end{aligned} \quad (11)$$

$$\bar{\bar{ID}} = ID - ID_t \quad (12)$$

RESULTS AND DISCUSSION

The proposed control approach for cancer chemotherapy was executed using MATLAB 2018a. Analysis was conducted using the chemotherapy nominal parameters listed in Table 1. Furthermore, suggested NEF-EKF-ISF control model's efficacy was compared to other established techniques, encompassing EKF [10], AEKF [27], as well as NEF-EKF [28]. Findings clearly show that NEF-EKF-ISF is superior at controlling states (tumor, normal, immune cells).

Table 2. Nominal Chemotherapy Parameters

Parameter	Value
y_1	0.05
y_2	0.15
y_3	0.1
ra_1	1.5
ra_2	1.0
t_1	0.2"
q_1	1.0
q_2	0.5

q_3	1.0
q_4	1.0
c_1^{-1}	1.0
c_1^{-2}	1.0
st	0.33
α	0.3
ρ	0.01

Convergence Analysis on injecting Drug Dosage

Figure 1 provides a graphical representation of chemotherapy drug dosage and that guide normal, immune, as well as tumor cells toward their respective desired values. Since the primary goal of this work is to achieve convergence to optimal values, the proposed approach ensures convergence by delivering precise control signals to all states. The improvements in achieving the desired values through the proposed model are depicted in Fig. 4(1).

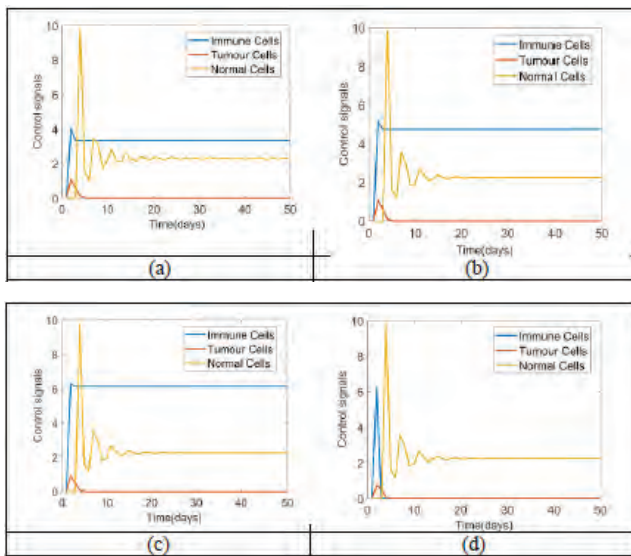


Fig. 1: Convergence Analysis under chemotherapy drug dosage (a) EKF (b) AEKF (c) NEF-EKF (d) NEF-EKF-ISF

Overall Performance

Table 3 demonstrates comprehensive efficacy of proposed method in monitoring desired values of states (immune, normal, tumor cells) concerning established techniques. The analysis reveals that the presented control strategy achieves values closest to the desired targets when compared to other models. Tumor cells exhibit lowest estimated values, signifying their effective elimination.

Consequently, the proposed NEF-EKF-ISF model demonstrates superior parameter estimation capabilities compared to conventional techniques.

Table 3. Overall Performance of Proposed Control Theory Over Other Conventional Theories

	EKF [10]	AEKF [27]	NEF-EKF [28]	NEF-EKF-ISF
Immune Cells (mol)	1.3394	1.2686	1.2119	1.0453
Tumour Cells (mol)	0.024439	0.02461	0.021895	0.020437
Normal Cells (mol)	0.87244	0.84626	0.84626	0.84626"

CONCLUSIONS

This work presented an innovative, robust controller aimed at regulating drug dosage while concurrently estimating system characteristics. The proposed NEF-EKF-ISF methodology included a revised procedure based on a prior error function, modified for a nonlinear context. A scaling factor was included to address historical error enhancements throughout updating process.

Efficacy of developed controller was assessed in comparison to conventional approaches, demonstrating its superiority in regulating drug dosage injections across normal, immune, and tumor cell states. The analysis of the system's time response demonstrated stable tracking of target values, especially for tumor cells, when the modeled observer was present. Notably, at an error value of -0.4, control signal performance of proposed approach outperformed EKF, AEKF, and NEF-EKF methods by 60%, 80%, and 20%, respectively. These results confirm the capability of NEF-EKF-ISF model in accurately estimating parameter values and achieving optimal state control.

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An Overview of Effect of Electric Vehicle Charging Station on MV Distribution System

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ABSTRACT

As an alternative to more traditional modes of transportation, electric vehicles, or EVs, are becoming more and more popular. Additionally, the number of EV charging points is rapidly growing. Because of their different features, if a lot of cars start charging at once, the distribution system transformer will be overburdened, which will cause it to age and raise its temperature. A number of factors, such as the effect of the different Electric Vehicle chargers on the distribution grid, the mobile nature of EV demand, system reliability, voltage regulation, and scatter demand of the load curve, must be taken into consideration when analyzing the effects of additional EV load to the current low voltage distribution system. This study offers an overview of numerous studies that have suggested a variety of methods.

KEYWORDS : *Charging station, Energy management, Distribution system, Transformer aging, Electric vehicle.*

INTRODUCTION

Amazingly, electric vehicles (EVs) have become a viable replacement for internal combustion engines [1]. The commercialization of electric vehicles (EVs), which offer a viable alternative to reducing fossil fuel usage and greenhouse gas emissions, is expanding quickly [2].

The International Energy Agency reports that over 750 000 electric car sales occurred globally in 2016, setting a record for new registrations [3]. A favorable environment for the efficient usage of EVs is also created by the smart grid, it combines distributed photovoltaic generation, battery storage devices, and advanced communication technology.

Plug-in electric car use is rising, but there are additional obstacles to their efficient grid integration, especially given the unknowns surrounding EV owners' behavior [4]. A huge amount of power can be consumed if many EVs start charging at once, which could cause a distribution transformer overload. This overloading raises the operating temperature of the transformer and could cause it to fail due to loss of life [5].

There have been some studies suggested in this field, and they mainly analyze the effects on transformer failure and suggest clever charging techniques to prevent transformer ageing.

Uncoordinated EV demand's effects on residential areas' ageing transformers have been examined in some studies [6,7]. Probabilistically estimating the effect of charging of EV on loss-of-life of distribution transformer while taking into account a residential area with solar generating (PV) has been investigated [8].

In a residential area, the impact of PV generation on lowering distribution transformer ageing brought on by charging EVs is investigated in [9].

There is an increasing need to comprehend the effects that Plug in Electric Vehicle charging loads will have on the infrastructure for electricity distribution as bulk plug-in hybrid and battery electric vehicles (collectively known as PEVs) are currently available for purchase or are slated for release.

The effects of PEVs on gasoline use [10,11], power plant emissions [12,13], electricity costs [14,15,16], transmission sufficiency [17], and generating supply

sufficiency [16,18,19] have been the subject of extensive research. The literature on the effects of low and medium voltage distribution systems, however, is relatively sparse and provides utilities intending to include PEV impacts in their maintenance and investment plans with less direction.

There are several factors that come together to make it necessary to quantify the impact of Plug in Electric Vehicles on the medium and low voltage distribution systems.

First, the societal benefits of PEV deployment, such as less oil consumption and reduced life-cycle greenhouse gas emissions, have prompted state and federal policies aimed at speeding up the rate of PEV adoption.

Second, it is probable that PEV sales will be focused in specific regions because early adopters of PEVs are probably driven, at least in part, by concerns about the environment and because prior sales of hybrid electric vehicles have shown that consumers of environmentally motivated vehicles are going to be geographically clustered.

PEV charging loads will affect local distribution systems due to this clustering long before they have a major effect on transmission or generation infrastructure. To handle this additional load, distribution utilities may need to spend significantly in infrastructure in high-adoption areas if, as indicated, these effects are severe. For these investments to be implemented effectively, accurate information on PEV consequences is necessary.

EV charging loads are distinctively different from conventional fixed node-connected loads in that they are mobility. Without taking into account these elements, solutions may be proposed that cause grid congestion and ensuing over/under compensations. These dynamics offer a chance to address some of the grid integration issues related to EV needs, even though they also pose challenges for a stable grid.

Therefore, it is necessary to examine the impact of adding EV charging load to the current low voltage distribution system by taking into account a number of factors, including the spread/peak demand of the load curve, power quality, voltage profile, and grid impact with various EV chargers.

This paper is organized in different section I Introduction II. Literature Survey, III. Methodology IV Discussion, V. Conclusion

LITERATURE SURVEY

[20] This paper serves as a supplement to the prior literature, as it thoroughly examines the most important aspects of EV integration; The impact of rising EV load penetration levels on the voltage profiles of various low-voltage distribution systems is illustrated through modelling case studies, which is one of this work's major contributions. The California load curve example study is used to first show how growing penetration levels affect grid stability and peak demand of various load curves. A thorough analysis of comparable studies carried out globally is then done. [21] The review of multi-level EMSs at the aggregator, grid, and residential levels is the main topic of this paper. There are also some present difficulties with the hierarchical EMS introduced, as well as some potential directions for future research, such as the Smart Transformer, Reactive Power with EMS, and Uncertainty Factor of EV. The comparison of temperature-based regulation to many alternative smart charging strategies is also included. [23] The following are the anticipated goals and contributions of the suggested work: To address the true pattern of PEV daily driving cycles, a statistical spatial-temporal (SAT) distribution model is being developed. With SAT models of PEV charging load, the unpredictability of PV generation (i.e., temperature and irradiance) and conventional loads is modelled and integrated. In order to prevent DT overload and to improve and extend DT lifetime, a control technique utilizing various generations of home battery energy storage (HBES) is presented. Additional study is needed to address the methods to lessen the influence on transformer life. [24] In order to synchronize EVs and BESS in an ideal manner and prevent transformer overloading in a parking garage for a commercial building powered by PV, this article suggests a smart charging strategy. In order to reduce energy consumption costs in a commercial building parking garage, provide a smart charging technique that coordinates EVs and BESS while PV generation is present, taking transformer maximum capacity into consideration as a constraint; only case study results have been reported; general results need to be determined. Analyze the effects on transformer highest temperature and loss-of-life, taking into account the effect of changes in the ambient temperature using localized meteorological data. [25] Our paper's key contribution is the suggestion of a clever fuzzy logic-based decision-making method. The fuzzy method enables taking into account the comfort of the EV owner as well as the battery's state of charge, the amount of charge needed for the subsequent trip, and

the anticipated time of EV departure. [26] For one day, a case study was conducted, in contrast to other studies where the analysis was carried out for the steady-state condition of the system (without taking the load curve into account), or fewer scenarios and EV models, this research analyzed the effects of electric vehicles regarding the voltage level, power demand, and active power losses for different penetration levels and power demand scenarios [37]. In each situation, the voltage level dropped, but it stayed within the permitted range. [37] Future research could involve increasing the number of electric vehicles to the point where the power demand is equivalent to the power requirement of the bus. The charging process can be examined over a longer period of time, whether the electric vehicles are connected at the same time or at various times. [27] In this work, DT ageing difficulties brought on by the demand for EV charging are evaluated quantitatively and solutions are suggested, in particular, this study examined the demand for EV charging in a densely populated apartment complex. In order to manage the excess power demand brought on by Electric Vehicle charging, it is necessary to anticipate and reduce the impact of Electric Vehicle recharging on distribution network for the power system and Electric Vehicles to operate reliably. It goes without saying that Electric Vehicle operation requires charging, and the DT is one of the primary network interfaces for power delivery. Both EV users and occupants of the apartment complex would experience service interruptions as a result of the failure or deterioration of such crucial equipment. [28] This survey exclusively analyses the effects of distributed generation on the distribution grid in order to keep the review focused. The report provides a quantitative evaluation of the body of research on PV impact. The effect of rooftop solar energy on the distribution system is also discussed in this research. [28] This report proposes that it would be crucial to consider the behavior of the distribution grid in the presence of substantial PV penetration. The occurrence of high PV penetration alongside high penetration of other small-scale energy sources, such as low-power wind turbines, communal energy storage systems, and/or electric vehicles, is another something that needs to be taken into account. [29] According to this study, the impact of system reliability (EENS) may also be examined using the fundamental system reliability indices, including predicted energy not supply, system average interruption frequency index (SAIFI), and system average interruption duration index (SAIDI). [30] This study used largely

simple models to examine the effects of EV proliferation in a particular urban setting. Even so, the results can serve as a guide for alternative setups and more complex modelling techniques. [30] The change in setup or model might be interpreted within the provided framework in order to generalize the results. [30] If EV owners, for instance, charge at work, they would only be able to meet around 75% of their daily energy needs at home, which would be the grid region of interest. [31] The negative effects of EV integration on distribution network, notably the Lol of distribution transformers, are examined in this article. [31] This occurs mostly as a result of transformer overloads causing permanent damage to insulating papers and oil. [31] This study suggests a solution for sizing BESS to accommodate the combined load of new EVs and residential demand in order to address the aforementioned issues without leaving any load unsupplied. [31] Future research could, for instance, look into the impact of price elasticity on the suggested algorithm. In order to better comprehend the effects of sizing BESS depending on the thermal loading of the transformer, demand response based on incentive-based programs could also be added. [32] In order to plan and operate the power distribution system to suit the dynamics of PEV charging demand, this paper provides an overview of the modelling of PEV charging load demand. [32] This article makes a few recommendations for additional research, including “Co-planning of DG and PEV charging infrastructure: As was mentioned, adding DG units to the distribution system can lessen the harm that PEV loads do to the system. [33] This paper’s first section examines the state of EV battery charging technology at the moment. For each level of an EV charger, the most popular topologies that are suitable candidates have been provided. The so-called onboard charger, which uses Level 1 and level 2 charger topologies, is typically located inside the car. Level 3 chargers, on the other hand, are situated outside of the vehicles. As a result, their gathering creates the so-called FCSs, which offer hope for future EV high adoption. Multilevel converters, which have a high-power density and a low current harmonic distortion, are the most popular technologies utilized in an FCS. Nearly all FCSs are combined with RESs and ESSs to lessen the influence on the grid; however, their effects must be researched for future investigation.

We can summarize the literature review as more research is required to determine the best way to place DG units and PEV charging facilities in the distribution system at the same time while taking unpredictability in both DG output and PEV load into accounts.

Issues like flickers, fault current, harmonic distortions, and voltage regulation should all be addressed by the co-planning problem.

It is not an easy undertaking to integrate new operational concepts for the distribution system to handle the co-existence of various technologies.

To handle the numerous random occurrences in the system, a stochastic modeling of the system is required. System security and reliability analysis are crucial.

METHODOLOGY

Problem Statement

From the literature it is clear that, Power quality and grid stability suffers when EVs are added to the current distribution line infrastructure due to their high penetration rates. Unlike other fixed node-connected loads, EV charging loads are defined by their ability to move. Grid congestion and the ensuing over/under compensations could arise from proposing solutions without taking these factors into account.

The addition of renewable energy to fulfill the demand of EV Charging station will significantly affect on the behavior of distribution system, as they are connected with various converters in the grid. Thus, the effect of adding EV charging load along with renewable energy, to the existing Low / Medium voltage distribution system need to be analyzed.

The investigation of performance of the distribution system with and without penetration of electric vehicle charging station is needed. Also, the performance of various devices connected in the distribution system must be analyzed for effect on their aging, thermal loading, etc., the voltage profile of the system under different situation need to address separately for better performance of the system.

To mitigate the different problems identified from the investigation will be addressed by using different techniques, using appropriate software.

Performance of Distribution system without the presence of Electric Vehicle.

Simulation study will be carried out for low voltage distribution system by considering appropriate design parameters to investigate the performance of the distribution system without penetration of Electric Vehicle Charging station using MATLAB

Estimation of the Electric Vehicle Charging Demand

The power demand profile for an apartment complex is obtained by modeling the specific parameters that drive the EV charging demand in order to investigate the impact of EV charging power demand. In particular, it's important to figure out how much power is needed and how demand changes throughout the course of a 24-hour period [27].

The research in this study will take into account the strategy shown in Fig. 1. Data that characterizes vehicle usage, user charging habits, and EV charging parameters are employed, as illustrated in Fig 1.

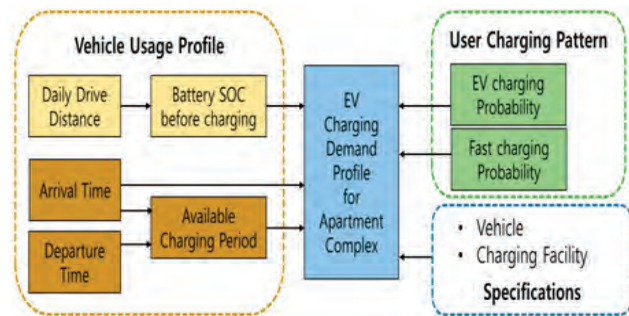


Fig. 1: Electric Vehicle Charging Demand Estimation

Along with the specifications of the charging station, such as the number of charging facilities accessible at a specific place, as well as EV charging patterns, For the purpose of estimating charging demand, charging probability and charging patterns—whether fast charging or moderate charging patterns—must be taken into account.

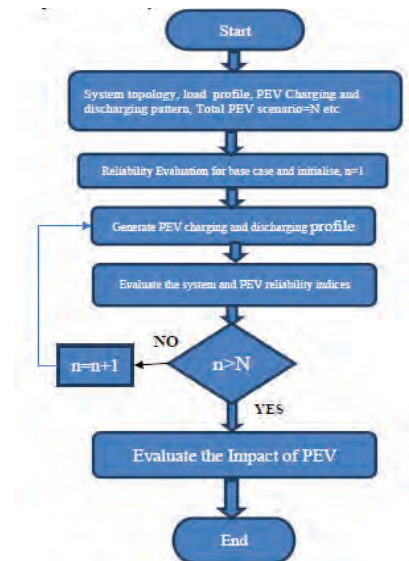


Fig 2: Assessment of Impact due to PEV

Assessment of impact due to Plug in Electric Vehicle

For the assessment of impact due to high penetration of PEV on the performance of distribution system different parameters need to monitor like charging station topology, maximum capacity of the charging station, load profile, charging and discharging pattern, No. of charging point available, etc.

Details flow of the proposed process will be as below which may need to modify as per the changes in the parameter and system behavior.

RESULT AND DISCUSSION

The advancement in the use of Electric Vehicle will lead in the expansion of charging station infrastructure which will result in harmful effect on the devices connected in the low voltage distribution system,

This study presents an overview of different effects on the distribution system due to increased demand due to expansion of charging station infrastructure like sudden rise in energy demand, transformer ageing, poor voltage quality, etc.

To resolve the problems associated with this can be addressed by different ways. This study proposes a method to analyze the electric vehicle charging demand as well as assessment of impact due to Plug in Electric Vehicle. This study has not obtained the final result yet but it gives a direction for the analysis of distribution system in the presence of Electric vehicle charging station.

The future work of this study will give a brief summary of charging pattern and also it will propose charging time duration for different users which can further be analyzed to flatten the demand curve.

The different impacts on the devices connected in the distribution system will be studied and ways to minimize the impact on the aging of transformer, voltage quality improvement etc. can be studied in the future work.

CONCLUSION

Numerous factors, such as the impact of various EV chargers on the grid, the mobile nature of EV demand, system reliability, voltage regulation, and scatter demand of the load curve, must be taken into consideration when examining the effects of adding EV charging load to the current low voltage distribution system, according to the literature. This study provides a review of many studies in

which various techniques have been proposed to enhance the effectiveness of the low voltage distribution system; it also provides future guideline which may improve the system performance.

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Solar System Design, Operation and Installation

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ABSTRACT

India has a huge potential for producing solar energy. Because of its geographic location, the country is perfectly positioned to generate solar energy. The reason for this is that, being a tropical country, India receives 3,000 hours of sunshine a year, or almost constant solar radiation. Approximately 5,000 trillion kWh is its equal. In almost every part of India, 4–7 kWh of solar radiation are received per square meter. Between 2,300 and 3,200 hours of sunshine are received annually. States like Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, and West Bengal are very promising for using solar energy because of their physical location. Since most people live in rural areas, there is a lot of space to encourage solar energy.

KEYWORDS : *Green energy production, Solar energy, Solar mission, Solar radiation, Solar power projects.*

INTRODUCTION

The Earth's conventional and non-renewable energy sources, such coal, gasoline, diesel, and so forth, are steadily running out of supply. As a result, the necessity for alternative energy sources like solar, wind, and bioenergy was recognized. These energy sources are referred to as renewable or non-conventional. Solar energy is thought to be the greatest and most widely used since it is free and abundant in nature. People frequently picture movable highway signs with a small panel attached or big blue or black solar panels on rooftops when they think of alternative or renewable energy. These solar panels, sometimes referred to as photovoltaic modules, or PV modules, are capable of generating power from sunlight.

METHODOLOGY

The step by step installation of solar panel

The Earth's conventional and non-renewable energy sources, such coal, gasoline, diesel, and so forth, are steadily running out of supply. As a result, the necessity for alternative energy sources like solar, wind, and bioenergy was recognized. These energy sources are referred to as renewable or non-conventional.

Solar energy is thought to be the greatest and most widely used since it is free and abundant in nature. People frequently picture movable highway signs with a small panel attached or big blue or black solar panels on rooftops when they think of alternative or renewable energy. These solar panels, sometimes referred to as photovoltaic modules, or PV modules, are capable of generating power from sunlight.

Arrange the photovoltaic PV modules

After the PV has been brought out, the specifications behind the panel will show the maximum wattage, voltage, and amperes. Although I personally prefer a parallel connection (the voltages remain constant while the current is raised), the panel should then be connected in compliance with the relevant regulations. The PV should then be installed on the building's roof, spaced a few inches apart and parallel to the roof's surface. Solar PV can also be installed on the ground. The ideal location for a solar array is usually perpendicular to the sun's beams, which vary depending on the time of day and season. The ideal location and inclination for a PV setup is the east front, which has a slope of 30 to 40 degrees.

Charge controller

Once the solar PV array is configured, connect the charge controller directly from the array's output terminals using lighter gauge cables. DC loads can be directly connected to the charge controller. After the connection, the battery must be connected. [2]

Battery

Depending on your needs, the batteries are correctly connected in either parallel or series. Following that, connect the battery to the solar charge controller at the designated connector. The inverter is the next component to be connected. [2]

Inverter

In order to power our AC loads, the inverter, which we covered previously, transforms the DC supply from the solar PV into an AC supply that is stored in the battery. Use a 2.5mm cable to connect the battery terminal to the inverter. Lastly, you connect the inverter to the house's external load. The PV array's rating and the inverter's rating ought to match.

Site selection criteria**Mounting location**

Typically, solar modules are installed on roofs. PV modules can be positioned on poles, the ground, the wall, or as a component of a shade structure if roof space is not available.

Shading

Solar arrays are negatively impacted by shade. The sun's rays must be unobstructed and available to a well-designed photovoltaic system from roughly 9 a.m. to 3 p.m., every day of the year. Even little shadows, like the shade from a single leafless tree limb, can significantly reduce a solar module's power output. Steer clear of skylights, gables, overhangs, vents, and attic fans that could shade the building itself. Keep in mind that an area could be unshaded at some periods of the day and shaded at others. Furthermore, a location that receives no shadow in the summer may receive shade in the winter due to the lengthier winter shadows.

Orientation

In northern latitudes, PV modules are ideally oriented toward true south, according to conventional wisdom. However, a roof's tilt or orientation does not have to be

precise because solar modules produce 95% of their power when positioned within 20 degrees of the sun's direction. Roofs that face east or west may also be suitable. Flat roofs are the best option since the PV modules may be positioned on frames and tilted up toward true south. The ideal orientation may be impacted by typical local weather patterns.

Tilt

To maximize the output of the solar power system, especially in PV solar array applications, the optimal tilt angle is often chosen for non-tracking systems and remains constant. Since higher tilt degrees structurally increase the wind load on the solar panel, a larger ballasted foundation would be required. In order to eliminate overshadowing from adjacent rows, higher tilt degrees might also require wider rows. A reduced tilt angle is commonly employed to minimize wind forces and minimize the size of the ballasted footing. This would not be feasible in areas with a lot of snowfall, where a larger tilt angle would be required to effectively remove snow from the solar module. Furthermore, a reduced tilt angle lessens the possibility of overshadowing in.

Required Area

Small commercial systems require space that ranges from 50 square feet to 1,000 square feet. For every 1,000 watts of PV, modules using crystalline silicon, the most common type of PV cell at the moment, require 100 square feet of collector space. In regions west of the Cascades, 1,000 kWh may be produced annually by PV modules with a 1,000 watt capacity apiece, whereas in regions east of the Cascades, 1,250 kWh can be produced annually. It will be necessary to about double the area of the less effective modules, such as amorphous silicon or other thin-film types. If the site limits the physical size of the system, it should be essential to install a system with more energy-efficient PV modules.

Roof Types

Slate and tile roofs are usually the most challenging to deal with when it comes to roof-mounted equipment, while composite shingles are usually the easiest. PV modules may be installed on any kind of roof. To save money on removing and reinstalling the PV system, the roof should be replaced when the system is installed if it will need to be changed in the next five to ten years. For new construction or for an existing roof that needs to be replaced, building integrated PV (BIPV) modules—which may be installed

into the roof itself—might be taken into consideration. Although BIPV devices are currently expensive, prices are anticipated to drop.

Grounding Equipment

Grounding equipment protects your system against current surges caused by lightning strikes or equipment failures by providing a clear, low-resistance channel from your system to the earth. In addition to providing a shared reference point, grounding stabilizes voltages. Typically, the grounding harness is found on the roof. [3]

Equipment Grounding

Every part of the system, including equipment boxes, outlets, appliance frames, and PV mounting equipment, as well as any exposed metal, should be grounded. [4]

System Grounding

One conductor from a two-wire system must be connected to ground in order to ground the system. This entails connecting the negative conductor to ground at a single location inside a DC system. Instead of at the PV array, this has to be done within the inverter.

Surge Protection

Surge protectors can help safeguard your system from power surges in the event that lightning strikes the PV system or nearby power lines. A power surge is a voltage spike that is significantly higher than the desired value.

Safety During the Installation

PV systems that are located on the roof necessitate the use of subcontractors, such as electricians. Making ensuring the installer adheres to safe installation procedures is the builder's legal obligation. The builder may be subject to hefty fines for failing to use the appropriate safety equipment. The fact that solar modules produce DC power when exposed to light is a risk unique to PV systems. PV systems may also draw power from a variety of sources,

including modules, the utility grid, and maybe batteries. Module and other electrical component manufacturers will issue safety instructions that must be strictly adhered to. Heaving modules onto a steep roof presents a risk in addition to the electrical ones. At least one safety eye for tying off must be placed when putting modules on the roof. The task is made easier and the installer has more freedom to move back and forth by installing two safety eyes and attaching the lanyard with a line between them.[2]

CONCLUSION

India has enormous potential for producing solar energy and stands to benefit from its geographic location. Solar power generation alone may be able to supply more than 60–65% of our entire power needs. We must therefore focus on carrying out our future plans for significant projects in Rajasthan and Jammu & Kashmir, even if Banda district in Uttar Pradesh is the most suitable location to satisfy our requirements. We must focus on rooftop solar energy generation in addition to the previously indicated, as this might lower our needs to more than 50% of those of every household.

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Color Image Encryption using Multiple Chaotic Maps

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ABSTRACT

In today's thriving digital age, the transmission of images across communication channels has exploded. The rising demand for innovative algorithms is fueled by the growing significance of ensuring the security of both sending and storing visual information. Image encryption is distinct from standard text encryption due to unique characteristics associated with images, including high pixel correlation and substantial data volume. Chaotic systems have gained popularity in cryptography because of their low processing cost, unpredictability, and sensitivity to initial parameters. This paper presents a chaotic image encryption method that utilizes a combination of the cosine polynomial chaotic map and the buffeting sine map. The outcomes of statistical analysis support its effectiveness in securing color images in all sensitive applications.

KEYWORDS : *Color image encryption, Chaotic maps, Statistical analysis, Cryptography.*

INTRODUCTION

Almost every technological field has included chaos theory since its inception in the 1960s.

Chaotic systems have been shown to be highly beneficial in applications that call for the usage of highly complicated systems, such as cryptography, because of their extreme sensitivity to parameter changes. It is important to create chaotic algorithms that offer both strong security and efficient computation. Recent cryptographic research [1], [2] targets encryption of grayscale images. Given the extensive use of color images, it is crucial to develop secure algorithms tailored to their needs. Chaotic maps can be classified into low dimension and high dimension (hyper chaotic) systems [3]. Simple mathematical forms are used for low-dimensional maps, reducing processing time. But their security is compromised because of predictable orbits and smaller key spaces.

The algorithms are developed to encrypt medical gray scale images [1], [2]. The color image encryption also has the potential applications. Chaotic maps' susceptibility to differential attacks stems from the lack of relation between

the initial conditions and the plain image. Also, the lack of uniformity in the histogram of the cipher image exposes certain algorithms to statistical attacks. Thus, the statistical analysis to test and validate the performance is essential.

In the proposed research, 3 different parameters depending on R, G and B planes of original color image are derived and utilized for 3-dimensional shuffling operation. Another 3 different keys are used in PRBG for XOR. The color image encryption using 3-dimensional shuffling is presented. The results of histogram analysis and mean square error are presented.

Encryption quality is also analyzed using maximum deviation and information entropy. The analysis indicates that the present algorithm provides high security and thus applicable for color image encryption.

LITERATURE REVIEW

In 2024, a novel chaos-based cryptosystem for securing sensitive grayscale medical images has been presented, which employs a 6D hyper chaotic system and diffusion using k-Fibonacci numbers. The simulations produced

good results, proving high security against numerous attacks. The cryptosystem beat contemporary encryption techniques and is capable of encrypting a wide range of medical images [1]. The authors mention that the work should be extended for color images.

[4] presents color encryption method using image hashing algorithm, 6D chaotic map and dynamic DNA coding. The image is resistant to numerous attacks, including noise and cropping, and can be analyzed to detect tampering, ensuring high security and resilience.

The novel block based encryption includes use of optical signals [5], fractional Fourier transform based logistic map [6] and Fibonacci sequence [7], [8] to raise security. Research on hyper-chaotic algorithms includes the design of fourth order systems for medical image encryption [9], [10].

The design and application of pseudo-random bit generator (PRBG) in encryption are discussed in [11]. A chaos-based image encryption technique using bit level cubic shuffling for enhanced security and resistance to various attacks is presented. The Shuffling and XOR are applied to plaintext image data. The security analysis is performed using statistical parameters. The algorithm offers secure encryption of the grayscale images. The research can be improved in the following ways: 1. Twelve different chaotic keys are used, 3 keys for each 1-dimensional shuffling and 3 keys for XOR. All 12 keys (including keys for XOR operation) are derived from single parameter λ , which depends on original image. So, if the encryption algorithm is known to the attacker, it can be cracked using brute force attack on λ . 2. The authors also mention that the extension to this work can be extended to the encryption of color images [11].

In [12], a common modulo-based hashing is used to generate bit streams using various chaotic maps and the performance is compared. Buffeting sine map is suggested as the best algorithm with respect to randomness, key space, and operations per bit ratio. To make the proposed algorithm secure, the buffeting sine map is modified and used for XOR operation. Thus, the system will be secured even if the shuffling keys are revealed.

The main novelties of this paper include

1. The usage of a novel plaintext-related parameter modification scheme for buffeting sine map. This secures the algorithm even if all-black or all-white images are applied to reveal the keys.
2. The

encryption operations extract the initial parameter values from plain image. So, the algorithm is resistant to differential attacks. 3. The uniform histogram of the encrypted image indicates the resistance to statistical attacks. 4. The 3 dimensional shuffling used in this work is more complex than 2-dimensional shuffling of rows and columns only. 5. Three different parameters depending on R, G and B planes of original color image are derived and utilized for 3-dimensional shuffling operation. Modified Buffeting sine map used for XOR operation employs totally different keys. Thus, the security against brute-force attack is increased. 6. Large key space offered using comparatively simple algorithm.

METHODOLOGY

The basics of shuffling

Invertible matrix is used to shuffle the image. The product of the invertible matrix and its inverse generates the identity matrix. So, the inverse of that matrix can be used for de-shuffling. The invertible matrix has a single 1 and all other 0's in the row. Rows of the matrix will be shuffled by left multiplication with invertible matrix.

Similarly, the columns can also be shuffled using right multiplication. The positions of 1's in invertible matrix decide the shuffling order.

The chaotic map for shuffling

The one-dimensional cosine polynomial chaotic map is used to generate invertible matrices for shuffling.

The authors have plotted the bifurcation diagrams for different μ values. The system presents highly chaotic behavior for μ values above 10. For higher μ values also, the system retains its constant chaotic nature for all values of constant c [11]. Three such cosine maps are used to shuffle image in all 3 directions.

The chaotic map for XOR operation

To make the algorithm resistant to brute force attack, different chaotic map is selected for XOR operation. In [12], the performance of 10 different chaotic maps on modulo based PRBG was checked. The authors suggest choosing the maps with at least 3 key values. Renyi, buffeting sine, IPE, Sine-Rem and PSE maps pass all NIST tests. SES, Buffeting sine and Sine-Rem provide maximum key space of 2^{213} . Renyi map uses minimum number of operations (0.75) per bit, but it has lower key space. Buffeting sine

and Sine-Rem maps also use less number of operations (1.25) per bit. Thus, looking at overall performance, Buffeting sine is selected for generating bit stream for XOR operation.

The basic Buffeting Sine map can be given as [12]:

$$x_i = \text{mod} \left[k \sin(\pi x_{i-1}) + \frac{b}{x_{i-1}}, N \right]$$

The basic map is modified as:

$$x_i = \text{mod} \left[k \sin(\pi x_{i-1}) + \frac{b}{x_{i-1}} + \frac{\sum_{i=1}^{\text{rows}} \sum_{j=1}^{\text{columns}} \sum_{m=1}^3 (p_{i,j,m})}{\text{rows} * \text{columns}}, N \right]$$

Where, $P=[p_{ijk}]$, $i=1$ to rows, $j=1$ to Columns, $k=1$ to 3 represents (rows,columns,3) plaintext color image. Thus, the bit stream generated will be different for different images.

THE PROPOSED ALGORITHM

Chaos-based image encryption methods should involve confusion and diffusion to initially crack the high correlation between neighboring pixels of the images and make it secure. Previous studies employ a variety of ways to guarantee this. The present algorithm proposes the use of chaotic 3D shuffling to break the correlation and chaotic PRBG to generate random bit stream which is XORed with shuffled image. The chaotic keys are derived from plain image.

The highly random bit stream is generated using buffeting sine map. As the x_i chaotic value is calculated from sum of all pixel values and the dimensions of the original image, the algorithm will be resistant to differential attacks. The detail algorithm is given below:

Color image Encryption Algorithm

For 3D shuffling, 3D color image matrix P ($M \times N \times 3$) is converted to 2D by keeping any 1 parameter constant. For example, for first step, plain image matrix is divided in M no. of ($N \times 3$) 2D matrices under same row. Rows and columns of these 2D matrices are shuffled using left and right multiplication with invertible matrices. The positions of 1's in invertible matrices are decided based on output of chaotic generator. Initial keys are derived from original image. This makes the algorithm highly random and secure against attacks.

Inputs: color image, 3 cosine chaotic map parameters, Buffeting Sine map parameters.

Encryption process

1. Read the color image to be encrypted (P).
2. Calculate the size ($M \times N \times 3$) of the image.
3. Calculate cosine polynomial chaotic map parameters.
4. Start with row level shuffling. For example, for 1st row, keeping row=1 constant, we will first shuffle columns and after that shuffle between RGB planes
5. Start with column level shuffling. For example, for 1st column, keeping column=1 constant, we will first shuffle rows and after that shuffle between RGB planes.
6. Start with RGB plane level shuffling. First of all, rows and columns of R plane will be shuffled. After that rows and columns of G and B planes will be shuffled one after another.
7. After the 3-dimensional shuffling, reshape the matrix in 1-row vector.
8. Generate the bit sequence using buffeting sine map and XOR with the binary stream.
9. Convert bits to integer again and arrange in ($M, N, 3$) matrix. Display the cipher image.

RESULTS AND DISCUSSION

This section presents detail results employing sample Lena, Pepper and Baboon images, which are taken from USC-SIPI database.

Histogram analysis

The intensity of pixels in an image is displayed through a histogram. The original and encrypted images as well as their histograms are presented in Figure 3. Figure 3(a) shows the actual images, Figure 3(b) includes their histograms, Figure 3(c) shows the shuffled images. Figure 3(d) shows the cipher images, and associated histograms are added in Figure 3(d). The encrypted images appear chaotic and filled with noise. The histogram of the original image displays clusters of pixels at particular intensity levels, while the histogram of the encrypted output is evenly distributed. Because the histogram of the cipher image obscures the original data, this approach provides robust defense against histogram attacks.

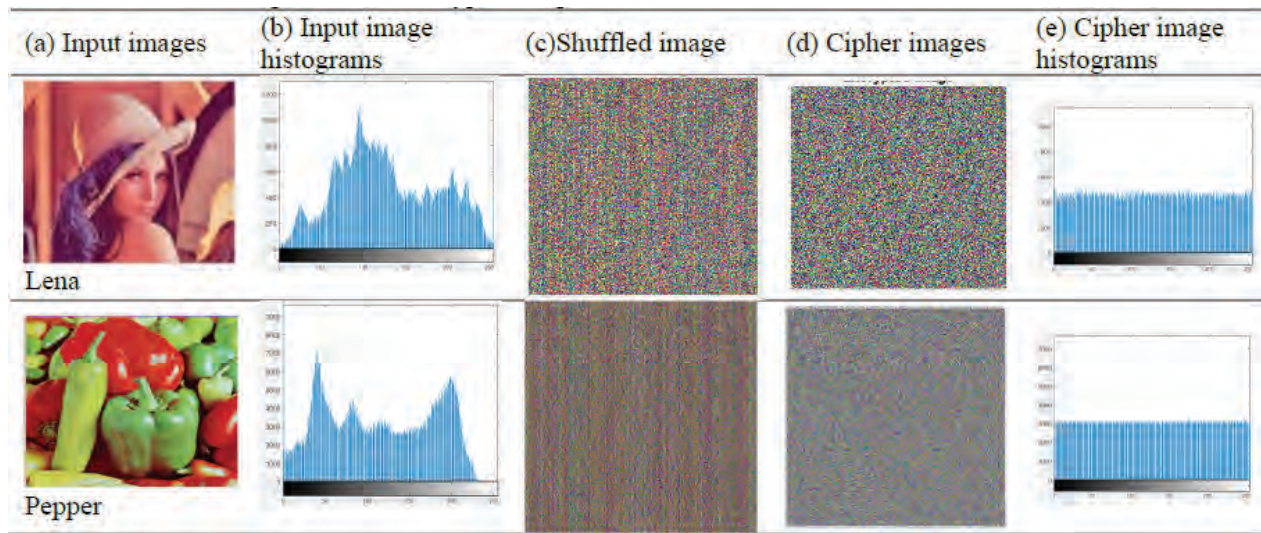


Fig. 3. Original and encrypted images with their histograms (a) input images (b) input image histograms (c) Shuffled image (d) cipher images (e) cipher image histograms

Information entropy

The statistical measure used to analyze confusion is called entropy H . The highest value it can have is 8. Entropy can be calculated using the following formula, where M is the total number of pixels in the image and p_i is the likelihood of pixel redundancy:

$$\text{Entropy } H = - \sum_{i=1}^M p_i \log p_i$$

Table 1 shows that the entropy values of the cipher picture are getting close to 8. Consequently, it demonstrates that the cipher image's pixel values are dispersed randomly. Therefore, it is quite challenging to deduce the true image from the encrypted image.

Analysis of encryption quality using maximum deviation

The difference in pixel values is assessed using maximum deviation. Plain and encrypted pictures should be completely distinct for good security. Therefore, there should be a large maximum difference between the input and cipher images. The algorithm's resilience to attacks is demonstrated by the high values for the cipher pictures in Table 2. It is assessed using:

$$\text{Max.Dev.} = \frac{D_0 + D_{255}}{2} + \sum_{i=1}^{254} D_i$$

Where D_i is the histogram value difference between the input and cipher pictures at index i .

Table 2. Entropy, Maximum deviation results

Table 2. Entropy, Maximum deviation results						
Sr. No.	Image	Entropy			Max. deviation	
		R	G	B	Encry. image s	Decry. image s
1	Peppers	7.99	7.99	7.99	235	0
2	Lena	7.99	7.99	7.99	255	0

Analysis of mean square error

The mean square error (MSE) findings for the sample photos are shown in Table 3. MSE evaluates the impact of avalanche. It demonstrates how the method may produce a notable variance in the encrypted image even with little adjustments to the input data or the key. The high value between the encrypted and input photos shows how different they are from one another. On the other hand, when the MSE between the input and decrypted photos is zero, the original image is correctly extracted with no loss.

Table 3. MSE results

Image	MSE for Cipher images			MSE (Decry.)		
	R	G	B	R	G	B
Peppers	7.9950e+03	1.1266e+04	1.1162e+04	0	0	0
Lena	1.0689e+04	8.8398e+03	7.2329e+03	0	0	0

The suggested algorithm has attained zero MSE for images after decryption. Consequently, our approach maintains the visual characteristics of the images following encryption and successfully reconstructs the original image without any loss. Additionally, the completely dissimilar histograms of the original and encrypted images demonstrate that the algorithm is resilient against statistical attacks. Recent studies, including those focused on encrypting medical images, have concentrated on grayscale images. Our algorithm is also applicable to color image-related applications.

In the results presented, the MSE for each cipher image is notably high. This suggests a significant disparity between the original and cipher images, making it challenging to extract original information from the encrypted version. Furthermore, for the decrypted images, the maximum deviation is zero, with correlation coefficients close to 0. These metrics demonstrate that the decrypted images are accurately reproduced without any loss. The findings align with earlier research studies [1] and [13].

Our algorithm facilitates effective randomization of image data by employing different chaotic parameters as secret keys. These chaotic keys are determined by the original image characteristics, which enhances the algorithm's resistance to differential attacks. The nearly perfect entropy and reduced correlation of the cipher images generated by our algorithm demonstrate that it offers improved security.

CONCLUSIONS

This study introduced an image encryption technique based on three-dimensional cubic shuffling. A secure pseudo-random bit generator was established utilizing a chaotic map foundation. The initial parameters are derived from the input image. Subsequently, a method for image encryption was developed. This method operates by first generating invertible matrices from chaotic maps for three-dimensional shuffling. An additional generator creates bits for the XOR operation. The encrypted image was implemented and evaluated using various security metrics, including entropy, histogram analysis, and both mathematical and visual correlation assessments. Consequently, the algorithm offers robust security against differential, statistical, and brute-force attacks, making it suitable for secure data transmission.

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Autonomous Agricultural Rover: Revolutionizing Precision Farming with Robotics and Automation

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ABSTRACT

Agriculture is the backbone of food production and sustainability. However, traditional pesticide spraying exposes farmers to toxic chemicals, and inefficient application methods can harm crops. This paper introduces an autonomous agricultural rover, designed to perform efficient and controlled pesticide spraying with minimal human intervention. Powered by an STM32 microcontroller, LoRa communication, and real-time video streaming, this rover offers precision in pesticide application, reduces labor costs, and enhances safety by allowing remote operation. This project embodies the principles of Precision Agriculture through the integration of robotics and automation, ensuring sustainability and efficiency in small and medium-sized farms.

KEYWORDS : *Autonomous rover, Precision agriculture, Pesticide spraying, STM32, Robotics, LoRa.*

INTRODUCTION

Agriculture plays an indispensable role in ensuring global food security and promoting sustainability. With the growing challenges of limited agricultural labor, pesticide misuse, and environmental degradation, there is an increasing need for innovative solutions to improve agricultural efficiency. In traditional farming practices, pesticide spraying is a physically demanding task that poses significant health risks to farmers due to exposure to toxic chemicals. Furthermore, uneven application often leads to ineffective pest control, resulting in poor crop yields and environmental pollution.

The autonomous agricultural rover introduced in this paper aims to address these challenges by automating the pesticide spraying process. This rover is equipped with a remote-controlled and autonomous spraying system that provides precise and controlled pesticide application. The system leverages an STM32 microcontroller for seamless operation, a LoRa communication module for long-range control, and real-time video streaming for operational monitoring.

By enabling remote operation, this rover significantly

reduces physical labor while ensuring safety and operational efficiency.

The rover is designed with small and medium-sized farms in mind, offering an affordable, efficient solution for pesticide spraying. This approach aligns with the principles of Precision Agriculture, where technology, automation, and data-driven decisions are used to optimize farming practices. This project seeks to revolutionize traditional farming by integrating robotics and automation, thereby improving productivity and reducing environmental and health impacts.

LITERATURE REVIEW

The use of autonomous systems for agricultural tasks, especially pesticide spraying, has garnered increasing interest in recent years. Several studies have explored the integration of automation, robotics, and IoT in agriculture.

Field Automation Challenges and Prospects (Singh et al., 2020)

This study focuses on the current state and challenges of field automation in agriculture. The authors highlight key advancements in robotics, sensors, and automation

technologies tailored for agricultural purposes. Despite these advancements, challenges such as field variability, crop complexity, environmental conditions, and cost constraints remain significant. The paper provides a comprehensive analysis of the potential benefits of agricultural robots in terms of precision, efficiency, and sustainability while also discussing the barriers to their widespread adoption [1].

Agricultural Robots for Spraying Pesticides in China (Zhai et al., 2019)

Zhai et al. explore the development of robotic systems for pesticide spraying, emphasizing their application in Chinese agriculture. The study reviews various designs and technological solutions, including autonomous navigation and spraying mechanisms. The authors discuss the integration of artificial intelligence, GPS, and vision-based systems for precise pesticide application, reducing waste and human exposure to chemicals. They also evaluate the practical challenges, such as operational reliability and adaptability to different crop types and terrains [2].

Automated Pesticide Sprayers for Precision Agriculture (Dharmaraj & Kumar, 2021)

Dharmaraj and Kumar review automated pesticide sprayers designed for precision agriculture. The study emphasizes the need for targeted spraying to minimize pesticide overuse and environmental impact. It evaluates existing designs and control systems, including GPS-guided sprayers, UAVs (unmanned aerial vehicles), and ground-based robots. The authors also discuss advancements in sensor integration and intelligent algorithms for plant health monitoring and real-time spraying adjustments [3].

Pesticide Spray Systems for Agricultural Robots (Sridhar et al., 2020)

This review focuses on the design and operational challenges of pesticide spray systems integrated into agricultural robots. Sridhar et al. examine nozzle designs, flow control mechanisms, and distribution techniques. They identify challenges such as ensuring uniform spray coverage, mitigating drift effects, and addressing maintenance issues. Potential solutions discussed include adaptive spray mechanisms, real-time monitoring of environmental parameters, and the use of machine learning for optimized spraying strategies [4].

Application of LoRa Technology in Agricultural IoT (Gutierrez & Villa-Henriquez, 2021)

Gutierrez and Villa-Henriquez present a comprehensive review of LoRa technology applications in agricultural IoT systems. They explore its advantages in long-range, low-power communication for monitoring and controlling agricultural operations. The study highlights the use of LoRa for soil moisture monitoring, weather data collection, and remote control of agricultural machinery. The authors emphasize the technology's potential to enable cost-effective and scalable solutions for smart farming [5].

Video-Based Real-Time Monitoring in Precision Agriculture (Martinez & Navarro, 2022)

Martinez and Navarro investigate the use of IoT cameras for real-time video-based monitoring in precision agriculture. The paper discusses advancements in image processing, machine learning, and edge computing for analyzing video data. Applications include plant health detection, pest identification, and yield estimation. The authors highlight challenges such as data storage, bandwidth requirements, and the need for robust algorithms to handle varying environmental conditions [6].

Agricultural Robot for Plant Health Detection (Mahajan et al., 2019)

Mahajan and colleagues propose an agricultural robot designed for plant health detection. The study outlines the use of sensors and image processing techniques to assess crop conditions and detect diseases. The robot employs a combination of visual data and environmental sensors to make informed decisions about pest and disease management. The authors emphasize the importance of precision in detecting early-stage plant health issues to improve yields and reduce chemical usage [7].

Integration of Autonomous Systems in Sustainable Farming (Chen et al., 2020)

Chen et al. delve into the role of autonomous systems in sustainable farming, focusing on their environmental and economic impacts. The study evaluates various autonomous platforms, such as robots and UAVs, used for tasks like seeding, spraying, and harvesting. The authors discuss the integration of renewable energy sources and energy-efficient components in these systems to enhance sustainability. They also address challenges like the initial cost of deployment and the need for robust training datasets for AI models to adapt to diverse farming conditions. Practical case studies demonstrate the systems' potential to optimize resource utilization and reduce the carbon footprint of agricultural operations [8].

AI-Powered Decision Support Systems in Precision Agriculture (Li et al., 2022)

Li et al. examine the application of artificial intelligence in decision support systems for precision agriculture. Their study highlights the use of AI models to predict pest outbreaks, optimize pesticide application schedules, and identify nutrient deficiencies. The research integrates data from IoT sensors, weather stations, and satellite imagery to create a holistic decision-making framework. The authors emphasize the importance of explainable AI for ensuring farmer trust and adoption. Furthermore, the study addresses challenges such as the complexity of data integration, scalability issues, and the necessity for region-specific models to improve the effectiveness of these systems [9].

Design and Development of Modular Agricultural Robots (Patel & Sharma, 2023)

Patel and Sharma investigate modular agricultural robots, emphasizing their flexibility and scalability for diverse farming tasks. The study reviews designs that allow modular attachments for spraying, weeding, and harvesting. The authors discuss the benefits of modularity in reducing overall costs and enhancing the adaptability of robots to different field conditions. They also explore challenges in standardizing interfaces and ensuring compatibility between modules [10].

Machine Learning in Pest and Disease Management (Kumar & Singh, 2024)

Kumar and Singh provide an in-depth review of machine learning applications in pest and disease management. Their study highlights the use of supervised and unsupervised learning techniques for analyzing agricultural datasets and identifying patterns of pest outbreaks. The authors also discuss the integration of ML algorithms with UAVs and IoT devices to enable real-time pest monitoring and targeted pesticide application. The research outlines the potential of ML to reduce crop losses and improve sustainability in agricultural practices [11].

Objectives

The primary objective of this project is to develop an autonomous agricultural rover capable of performing pesticide spraying with a high level of precision and minimal human intervention. The rover is designed to offer several key benefits to farmers, particularly those with small and medium-sized farms:

- **Precision Pesticide Spraying:** Develop a system that ensures even and controlled pesticide application, minimizing chemical waste and reducing environmental impact.
- **Remote Operation:** Implement long-range control through LoRa communication, allowing farmers to manage the rover remotely from a safe distance.
- **Autonomous Functionality:** Enable autonomous operation to reduce the need for manual labor while ensuring the rover performs the spraying task accurately and efficiently.
- **Affordable Solution:** Design the rover to be cost-effective, making it accessible to small and medium-sized farms that may not afford large commercial-grade sprayers.
- **Improved Health and Safety:** Ensure that the rover minimizes the farmer's exposure to harmful chemicals, reducing the risks associated with pesticide spraying.

METHODOLOGY

The architecture of the autonomous agricultural rover consists of several key components, each working together to ensure efficient operation. The rover is designed to function in both remote-controlled and autonomous modes, ensuring flexibility and adaptability to different farming environments.

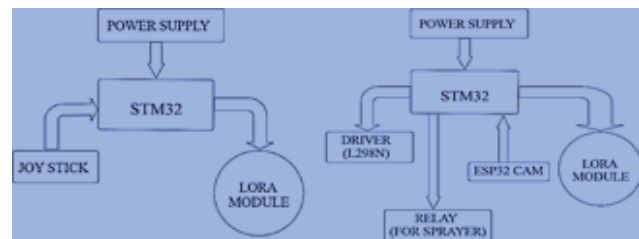


Fig. 1. System Design of Transmitter and Receiver

The block diagram illustrates the transmitter and receiver sections of an autonomous agricultural rover system. In the transmitter section, a joystick serves as the input device, allowing the user to control the rover's movement and operations. The joystick's analog signals are processed by the STM32 microcontroller, which converts them into digital commands for transmission. These commands are sent wirelessly using a LoRa module, which facilitates long-range communication between the transmitter and receiver. The transmitter section is powered by a dedicated power supply that supports all its components, including the STM32, joystick, and LoRa module.

In the receiver section, the STM32 microcontroller receives commands via the LoRa module and executes them by controlling connected components. The L298N motor driver manages the rover's motors, enabling movement in the desired direction, while a relay activates the pesticide sprayer based on specific commands. An ESP32 CAM module provides real-time video feedback for monitoring the rover's operations. This section is also powered by a dedicated power supply. Together, the transmitter and receiver sections form a system that allows the user to remotely control the rover for efficient agricultural tasks like spraying pesticides, with added capabilities for monitoring and feedback.

Proposed System and Methodology

The proposed system involves designing an autonomous rover capable of performing pesticide spraying tasks with minimal human intervention. The methodology is structured as follows:

Transmitter

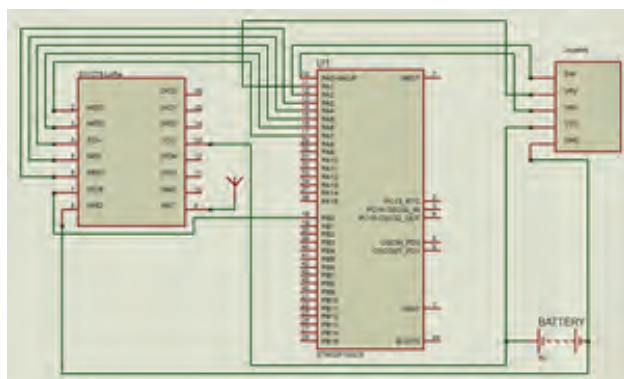


Fig. 2. Circuit Diagram of Transmitter

The diagram illustrates a hardware schematic for an electronic system likely involved in wireless control. At its core is an STM32F103C8 microcontroller, and 32-bit ARM Cortex-M3 processor, responsible for system logic and control. This microcontroller communicates with an SX1278 LoRa transceiver module via a SPI interface (MISO, MOSI, SCK, NSS) for wireless data transmission and reception. The LoRa module enables long-range, low-power communication, crucial for applications requiring extended reach and energy efficiency.

User input is likely provided through a joystick, generating analog signals corresponding to horizontal (VRx) and vertical (VRy) movements. These signals are read by the microcontroller's analog input pins. Other components

include a power supply, a reset circuit (NRST), and various GPIO pins for general-purpose input/output and external interrupts. The circuit also integrates a crystal oscillator for precise timing and system stability.

Receiver

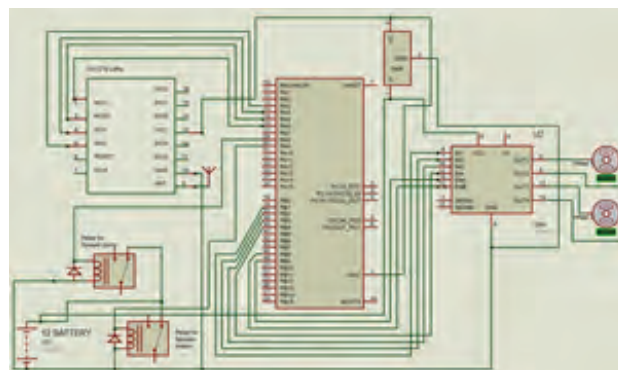


Fig. 3. Circuit Diagram of Receiver

This schematic depicts a control system likely for an agricultural application. At its core is an STM32F103C8 microcontroller, and 32-bit ARM Cortex-M3 processor, responsible for system logic and control. This microcontroller communicates with an SX1278 LoRa transceiver module via an SPI interface (MISO, MOSI, SCK, NSS) for wireless data transmission and reception. The LoRa module enables long-range, low-power communication, crucial for applications requiring extended reach and energy efficiency. The circuit also incorporates a 12V battery as the primary power source. Control and actuation are achieved through relays. One relay controls a sprayer pump, likely for applying pesticides or fertilizers. Another relay controls the "Sprayer Motion," suggesting the system is designed to move a spraying mechanism, such as a boom or nozzle. Additionally, an L298N motor driver is included, likely to control the movement of two DC motors, potentially for driving a mobile platform like a robot or rover. The microcontroller receives control inputs and processes them. Based on these inputs, it activates the relays to control the sprayer pump and motion, and drives the motors via the L298N driver. The presence of a "SENSB" input suggests the integration of a sensor, which could be used to measure environmental conditions, detect obstacles, or monitor plant health.

Technical Concepts and Algorithms

The technical implementation of the autonomous agricultural rover relies on several core concepts and algorithms:

Control Algorithm (Navigation and Movement)**A. Command Processing**

Switch between manual (LoRa input) or autonomous (grid-based) modes.

B. Motor Control

Use PWM signals for speed and direction; differential drive for turning.

C. Obstacle Avoidance

Detect obstacles with ultrasonic sensors and reroute using simple logic.

D. Feedback Loop

Maintain course using encoder data and optional PID control for accuracy.

Spraying Optimization Algorithm**E. Spray Activation**

Toggle the sprayer pump via relays in predefined zones.

F. Coverage Calculation

Match spray width with rover path to avoid overlaps/gaps.

G. Zone-Based Control

Use sensors to spray only pest-affected areas, reducing chemical use.

H. Feedback Monitoring

Continuously check spray pressure and flow for consistency.

Challenges and Mitigation

While the autonomous agricultural rover offers significant benefits, several challenges need to be addressed:

Terrain Variability**A. Challenge**

The rover may face difficulties navigating highly uneven or rough terrains, especially in areas with deep furrows or dense vegetation. The efficiency of the rover's movement could be impacted if the terrain is not suited for the wheels or the movement system.

B. Mitigation

Integrating high-quality sensors and advanced algorithms for terrain detection and adaptation can help address this challenge.

Battery Life and Power Management**C. Challenge**

The rover's battery life may limit its operation time, especially during long spraying sessions or large field coverage. The need for frequent recharging could reduce operational efficiency.

D. Mitigation

Optimizing power consumption by using energy-efficient components, such as low-power communication modules like LoRa, and implementing smart power management techniques can extend battery life. Incorporating solar panels for recharging could also help.

Signal Range and Interference**E. Challenge**

While LoRa communication is ideal for long-range, low-power transmission, signal interference in certain areas, such as fields with dense crops or natural obstacles, could affect the rover's ability to communicate effectively with the operator.

F. Mitigation

Enhancing the LoRa antenna and ensuring a clear line of sight or placing additional repeaters could improve signal strength. Alternatively, including a fallback communication mode in case of signal loss could ensure continuous operation.

Environmental Factors (Weather Conditions)**G. Challenge**

Harsh weather conditions such as heavy rain, high winds, or extreme temperatures could potentially affect the rover's sensors, motors, and overall performance, especially in terms of pesticide spraying accuracy.

H. Mitigation

Ensuring that the rover's components are weather-proofed and incorporating environmental sensors to monitor conditions can help adjust operation or pause spraying during unfavorable weather.

RESULTS AND DISCUSSION

This section presents the simulation results of the transmitter section of the autonomous agricultural rover. Due to the unavailability of joystick and LoRa module components in Proteus software, switches and LEDs have

been used as equivalents for the joystick and LoRa module respectively.

A. Transmitter Simulation Setup

In this simulation, the switches act as input devices to simulate the joystick functionality. The LEDs are used to represent the state of the LoRa module, indicating the transmission of control signals. The STM32 microcontroller receives input from the switches and sends appropriate control signals to the LEDs, simulating the transmission of data.

The circuit diagram of the transmitter section is shown in Figure 4. The switches are connected to the analog inputs of the STM32 microcontroller, which processes the input signals to control the LED output. Each switch corresponds to a specific control function, such as forward movement, reverse, left turn, right turn, or stop. The LED lights up when a control signal is transmitted, indicating that the corresponding command has been processed.

B. Simulation Results

During the simulation, the switches were operated in various combinations to simulate different movement commands. The results of the simulation show that the STM32 microcontroller correctly processes the input from the switches and controls the LEDs as expected.

CONCLUSIONS

This is for interpretation of the key results and to highlight the novelty and significance of the work. The conclusions should not summarise information already present in the article or abstract.

Can also mention the scope or possibilities of extension of research work or survey as scope for future work.

For instance, when the forward switch was pressed, the corresponding LED lit up, indicating that the forward movement command was transmitted. Similarly, pressing the left or right turn switches activated their respective LEDs, showing that the system responded accurately to different inputs.

The simulation also demonstrated the responsiveness of the system to multiple inputs. When multiple switches were pressed simultaneously, the system correctly processed and prioritized the commands, ensuring that the rover would move in the appropriate direction.

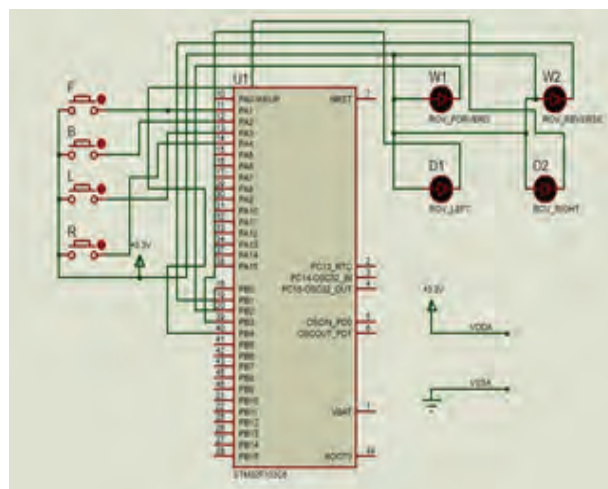


Fig. 4. Transmitter Section Simulation

C. Discussion

The use of switches and LEDs as substitutes for the joystick and LoRa module proved to be effective for simulating the basic functionality of the transmitter section in Proteus. Although this simulation does not replicate the full wireless communication functionality of the LoRa module, it provides a clear demonstration of the input processing and control signal generation.

Future improvements to this simulation can include integrating real communication modules and sensors to replicate more accurate field behavior. Additionally, more complex input patterns can be tested to simulate real-world scenarios, ensuring that the system is capable of handling a variety of control commands effectively.

In conclusion, the simulation of the transmitter section validates the basic functionality of the rover's control system. The successful operation of switches and LEDs in the simulation indicates that the rover's control and communication systems are working as intended in the initial stages of development.

The autonomous agricultural rover represents a breakthrough in the automation of pesticide spraying in agriculture. By combining robotics, automation, and remote control, the rover improves efficiency, safety, and environmental sustainability. It offers an affordable solution to small and medium-sized farms, significantly reducing labor costs and pesticide wastage. This project demonstrates the potential of Precision Agriculture and paves the way for a more sustainable, productive, and safe farming future.

ACKNOWLEDGEMENT

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Effects of Music Therapy on Plants in Controlled Environment

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ABSTRACT

The growth and physiological reactions of “Ocimum tenuiflorum” (Holy Basil), a medicinal plant noted for its sensitivity to environmental variables, which is examined in this study in relation to the benefits of classical music therapy. The study is meant to determine whether sound waves may improve physiological functions such as primary growth characteristics, root length, leaf area, and stem height. A control group that was not exposed to music and a treatment group that was exposed to classical music for 1 hour daily at frequencies between 300 and 400 Hz. A soil moisture sensor and a DHT11 temperature and humidity sensor were used to maintain a controlled atmosphere, ensuring consistent conditions. The plants in both groups received 250 millilitres of water each day and were housed in identical conditions. Over the course of eight weeks, data was gathered with an emphasis on physiological and growth parameters. The results showed that exposure to music had a positive impact on development and growth, with the treatment group surpassing the control group. According to the research, sound waves act as a mechanical stimulus to support plant health, providing a non-invasive, sustainable method of enhancing agricultural output and maximizing crop development in a variety of environments.

KEYWORDS : *Ocimum tenuiflorum, Classical music therapy, Plant growth enhancement, Controlled environment, Sustainable agriculture, Sound wave impact.*

INTRODUCTION

This study investigates the effects of music and sound on plant growth and health. Although the benefits of music therapy for humans are well established, new research suggests that it may also improve plant growth. Despite their inability to hear, plants are able to perceive vibrations from sound waves, which may help them grow, absorb nutrients, and maintain their health. By examining significant variables like leaf size, stem height, and, this study investigates whether exposure to music can have a beneficial effect on plant growth. All plants are kept in the same temperature, humidity, and soil moisture levels during the controlled experiment. One group gets exposed to music, while the other is not; that is the only distinction

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LITERATURE REVIEW

Manikandan S et.al.[1] proposed Music therapy,

particularly low-frequency sounds, has a significant positive impact on plant growth, making them stronger and disease-resistant. Sound vibrations influence plants' growth cycles, showing the potential benefits of sound therapy in agriculture. This method offers an innovative approach for improving plant health and development.

Akshat Gupta [2] proposed Research suggests that plants respond to sound vibrations, with music potentially improving their growth and well-being. While the belief that plants experience emotions isn't widely accepted, some studies show music therapy can enhance their health. If proven commercially viable, it could offer a natural solution to agricultural challenges.

Tejal Patel et.al.[3] proposed Music significantly influences plant growth, with soft, rhythmic music promoting health and development. Specific sound frequencies, like those between 115 Hz and 250 Hz, positively affect seed germination, root length, and height. Intense sounds like rock music hinder plant growth, suggesting that frequency and intensity are key factors.

Deepti Sharma [4] proposed a study that explores how music affects plant growth and biochemical processes. Exposure to soothing music led to better growth in various medicinal and ornamental plants. The research measured changes in chlorophyll, sugars, proteins, and phenols, highlighting music's potential influence on plant metabolism and overall health.

Dr. Ajay A. Gurjar proposed Vedic chanting and classical music both promoted plant growth, but Vedic chanting showed greater impact, with enhanced leaf size, shoot elongation, and internode growth. The study suggests that high-frequency sound waves, such as those in Vedic mantras, improve plants' physiological functions, leading to stronger, healthier growth.

BLOCK DIAGRAM

Plant: Holy Basil (*Ocimum tenuiflorum*)

Holy Basil, a fast-growing, aromatic herb from the Lamiaceae family, is ideal for research due to its adaptability, rapid growth, and rich phytochemical profile. Its sensitivity to sound vibrations influences nutrient absorption, photosynthesis, and secondary metabolite production, making it a strong candidate for music therapy and mechanostimulation studies.

Arduino UNO

The Arduino Uno, powered by the ATmega328P microcontroller, is a versatile platform for electronics

projects. With 14 digital I/O pins, communication protocols (UART, I2C, SPI), and compatibility with numerous sensors, it's ideal for prototyping. It is used as a central unit for data collection through soil moisture and temperature sensors.

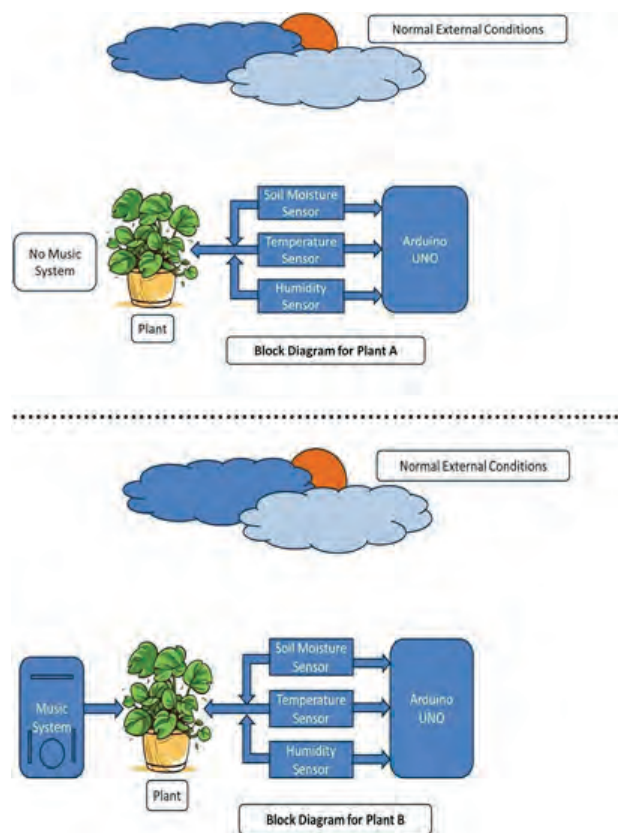


Fig. 1: Block Diagram

Soil Moisture Sensor

Soil moisture sensors measure water content using resistive, capacitive, or tensiometric principles. They monitor soil conductivity or capacitance, indicating moisture levels for irrigation and research. Capacitive sensors are durable and precise, while resistive types are cost-effective but prone to corrosion. The sensor is used for ensuring consistent watering of plants.

Humidity and Temperature Sensor: DHT11

The DHT11 sensor measures humidity (20–90% RH) and temperature (0–50°C) with $\pm 5\%$ and $\pm 2^\circ\text{C}$ accuracy, respectively. It outputs digital signals, is easy to integrate with microcontrollers, and is widely used in automation, weather stations, and environmental monitoring, offering simplicity and cost-effectiveness for basic data collection.

applications. It is used as a reference to ensure a similar and controlled environment for plants.

METHODOLOGY

Four identical plants (A, B, C, and D) of the same species and comparable size are chosen for the experiment in order to guarantee consistent initial conditions. A control group (C and D) and an experimental group (A and B) is formed from the plants. For a set period of time each day (for example, an hour), the experimental group will be exposed to a regular, relaxing kind of music, such as classical music. The volume is to be kept at a manageable level to prevent physical strain. Conversely, the control group will remain in the same setting without any auditory stimulation and will not be exposed to music.



Fig. 2: (Plant A and B) Experimental Group (in the beginning)

To maintain uniformity, all plants will be housed in identical environmental settings with controlled light, temperature, water, and soil type. All of the plants will receive the same amount of water and be kept in the same lighting conditions. Semiweekly measurements of growth characteristics, such as plant height (measured every two weeks), leaf count, and general health conditions, such as leaf color, disease symptoms, or wilting, is part of the data collection process. Any more noteworthy variations will also be noted. To give enough time for any noticeable impacts, the experiment will run for a set amount of time, such as eight weeks or longer. Keeping all ambient factors under control will guarantee that any variations between the groups can only be ascribed to their musical exposure.



Fig. 3: (Plant C and D) Control Group (in the beginning)

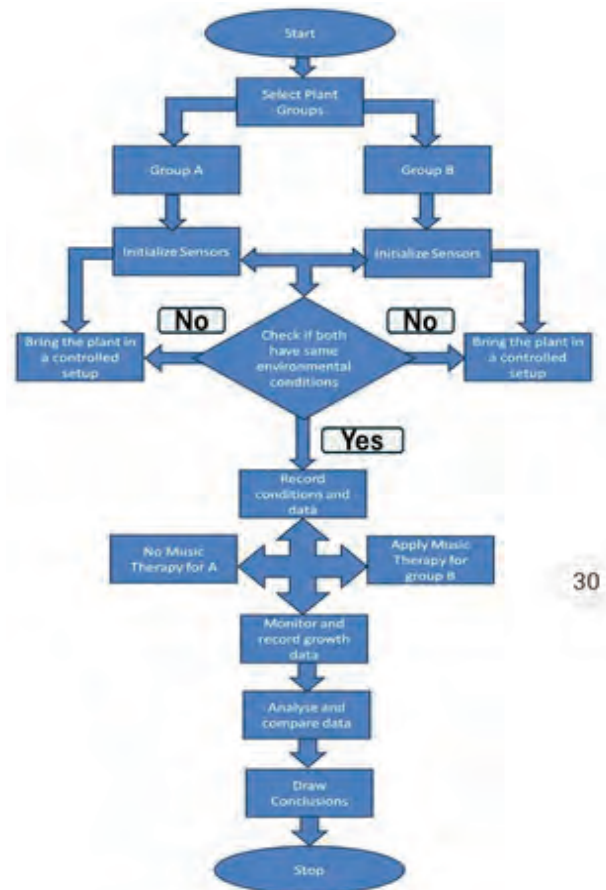


Fig. 4: Experiment Flowchart

RESULTS AND DISCUSSION

The experimental groups, Plants A and B, which were exposed to music, demonstrated significant growth advantages compared to the control groups, Plants C and D. The most notable difference was in plant height, as Plants A and B consistently outgrew Plants C and D throughout the observation period. This difference suggests that music exposure positively influenced growth rates. Additionally, Plants A and B appeared healthier, with their leaves displaying a deeper red hue, a characteristic of this Tulsi species that develops red pigmentation under favorable environmental conditions. This vibrant coloration was less pronounced in the control plants, further indicating the potential benefits of music exposure. Although all plants appeared healthy, Plants A and B stood out with their more vibrant appearance and stronger growth patterns. Interestingly, leaf count varied among the groups. Plant A and Plant D had more leaves compared to Plants B and C, indicating that while music exposure seemed to enhance growth and leaf pigmentation, it might not directly correlate with an increase in leaf numbers across all cases.



Fig. 5: (Plant A and B) Experimental Group(after 8 weeks)

All the data collected using Arduino, soil moisture sensor, temperature and humidity sensor is noted in the logbook and regular observations are maintained.

Overall, the study highlights that music exposure significantly contributed to the improved growth and vitality of Plants A and B. This was reflected not only in their increased height but also in their richer pigmentation

and robust health. The findings suggest that music can act as a growth-enhancing factor, promoting healthier and more vigorous plants compared to those not exposed to such stimuli. While all the plants appeared healthy overall, the experimental groups visibly exhibited superior vitality. The leaf count, however, showed variability across the groups. Interestingly, Plant A (experimental) and Plant D (control) had a higher number of leaves compared to Plant B (experimental) and Plant C (control). This suggests that while music exposure positively impacted growth and pigmentation, its influence on leaf count may not be consistent.



Fig. 6: (Plant C and D) Control Group(after 8 weeks)

The line graph highlights the effect of music exposure on plant growth. Plant B demonstrated the greatest height, followed by Plant A, both of which were in the music-exposed group. In contrast, the control group (Plants C and D) had shorter heights. Two significant events were recorded during the experiment. On December 27, there was a cloudy day accompanied by light rain lasting approximately 30 minutes, which may have temporarily affected the growth environment. Additionally, during Week 4, a branch of Plant C began turning black, and by Week 5, the branch broke off, reducing its height from 28.9 cm to 26.5 cm. Despite these occurrences, plants exposed to music consistently outperformed the control group in growth, suggesting that auditory stimulation may positively influence plant development.

The bar graph demonstrates notable variation in the leaf count among all plants. Plant D recorded the highest leaf

count at 149, followed by Plant A with 140 leaves. On the other hand, Plant C and Plant B had the lowest leaf counts, with 133 and 90 leaves, respectively. This variability suggests that the effect of music exposure on leaf growth may not be uniform across all plants. Furthermore, the number of fallen leaves over the eight-week period was also inconsistent, reflecting a similar pattern to the observed leaf count. While some plants retained more leaves, others experienced higher leaf shedding, showing no definitive trend between the experimental and control groups.

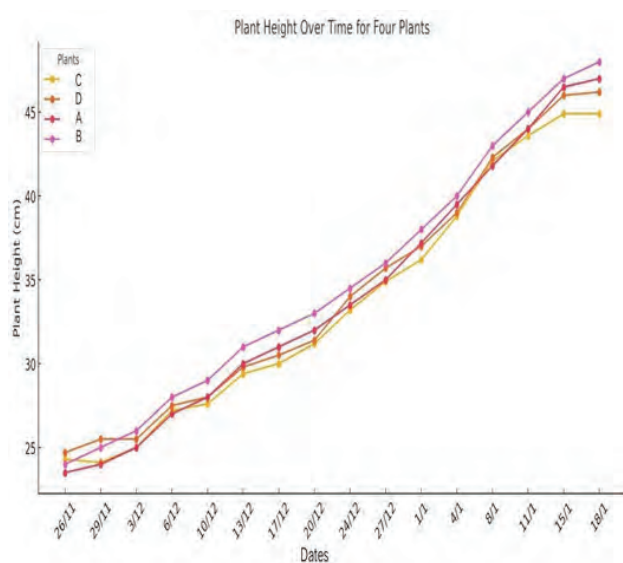


Fig. 7: Plant height Over 8 weeks

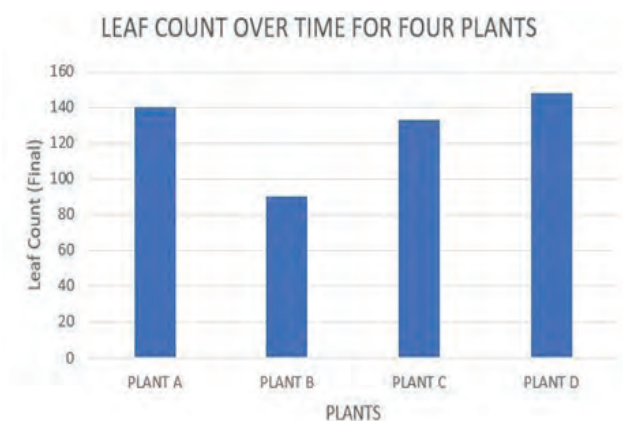


Fig. 8: Leaf Count on 8th week

The findings reveal that music exposure led to healthier and more robust plants, as evidenced by improved height, pigmentation, and overall vitality in Plants A and B compared to the control groups.

CONCLUSION

In summary, this experiment highlighted the positive impact of music exposure on the growth and overall health of Tulsi plants. Plants A and B, which were exposed to music, displayed greater growth in height and a more vibrant red coloration in their leaves compared to the control group, Plants C and D, which were not exposed. The deep red pigmentation, a characteristic of this Tulsi species, served as an indicator of improved plant health, emphasizing the influence of music on plant vitality. Although all the plants maintained good health throughout the study, Plants A and B exhibited more pronounced growth and pigmentation. The variation in leaf count across the plants was notable, with Plants A and C having more leaves than Plants B and D. This suggests that while music contributes to enhanced growth and pigmentation, its effects on leaf production may vary based on other factors, such as environmental conditions or genetic differences.

These findings suggest that music can be a beneficial stimulus for promoting plant growth and health in controlled settings. By encouraging taller plants with more vibrant pigmentation, music has the potential to be an innovative tool for enhancing plant development, offering valuable insights for sustainable agricultural practices.

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A Smart Cradle with Integrated IoT for Enhanced Infant Safety and Well-being

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ABSTRACT

This paper details the creation and implementation of an inexpensive and efficient real-time baby monitoring system called A Smart Cradle with Integrated IoT for Enhanced Infant Safety and Well-Being. To provide comprehensive care, the system makes use of a range of sensors. It can recognize a baby's screams using a KY-038 sound sensor and use a mobile app to notify the parents. A DHT11 sensor monitors temperature and humidity levels, and an automated fan is activated to give comfort when the temperature surpasses a preset threshold. Parents may monitor the baby and the environment from a distance with the help of a Wi-Fi-enabled camera that offers continuous 360-degree surveillance. An ESP32 Wi-Fi controller manages the entire setup, ensuring that all connected parts operate as intended. With the help of this innovative system, which offers real-time data and automatic features, parents can effectively care for their infants even when they are away.

KEYWORDS : *IoT, Smart cradle, Baby monitoring, KY-038 sound sensor, DHT11 temperature and humidity sensor, MH-RD rain sensor, Wi-Fi camera.*

INTRODUCTION

It can be difficult for many parents to balance the full-time responsibilities of caring for a baby with their employment obligations. Because of the rising expense of living, both parents frequently have to work, making it a big issue to make sure their infant is secure and comfortable while they are away [1]. Conventional approaches, such depending on family members or caregivers, don't always offer the degree of supervision required. This is the point at which technology can significantly reduce the strain of caring for a new born. Smart Cradle with Integrated IoT for Enhanced Infant Safety and Well-being was created to solve this issue. This state-of-the-art technology tracks a baby's health in real time using a range of sensors. A The method makes use of Internet of Things (IoT) technology to track the baby's condition remotely via an

internet platform or mobile app [2][3]. Constant updates on the baby's condition and surroundings are provided via features like movement detection, temperature monitoring, and sound detection, which provide parents comfort even when they are not there. A crucial component of the system is the incorporation of a Wi-Fi camera, which offers 360-degree monitoring of the infant's environment and condition, enabling parents to constantly visually check on their child [3]. This smart cradle's primary objective is to always make sure the infant is secure, cozy, and receiving proper care. The system has sensors that watch the infant's movements, look for dangerous positions for the new born, and keep an eye on the room's humidity and temperature. To keep the infant comfortable and peaceful, it can also modify surrounding elements like temperature and noise levels. The video surveillance feature adds an extra degree of protection by enabling parents to see their infant from

any location [3]. The quality of baby care is improved by this technologically advanced solution, which also makes it easier for working parents to make sure their kids are safe when they are away from home.

LITERATURE REVIEW

Author Mayuresh Khataavkar et.al presents Using Internet of Things (IoT) technology, the “Smart Baby Cradle Monitoring System” helps parents keep an eye on their infant. As the number of working mothers has increased and more parents rely on others to care for their children, baby care has become more challenging. This gadget enables parents to remotely check on their infant’s mobility, temperature, and moisture levels to guarantee comfort and safety. The smart cradle helps parents save time and effort by automatically swaying the baby to soothe them[4].

Author Anushree U R et.al presents “Smart Baby Cradle Monitoring System” to assist working parents with remote baby monitoring. The system makes use of a motorized cradle that swings on its own when the infant screams and Internet of Things technology. Through the Blynk app, parents can monitor their infant’s health and get alerts for things like crying, urinating, or waking up. The cradle is perfect for time-constrained parents because it has automated rocking and can be watched from anywhere at any time. The Arduino IDE was used to create the system, which is inexpensive, user- friendly, and may find utility in maternity hospitals [5].

Author Patel, A et.al presents a sensor-equipped Arduino Uno is used in “Design and Development of an Intelligent Baby Cradle System with Real-Time Environmental Monitoring” (DHT11 for temperature and humidity, sound for crying, and a rain sensor). When weeping is detected, the system uses a servo motor to rock the cradle. Real-time data is shown on an LCD, and alerts are transmitted to a caregiver’s Android smartphone. The sensors are controlled by an ESP32 controller, while a voice module produces calming audio. The system provides web-based application-based remote monitoring and control.

METHODOLOGY

Block Diagram

A clever child care cradle system that improves caregiving with little manual labor is depicted in this diagram. The ESP32 microcontroller, which combines multiple sensors and controllers, is at the center of the system. While a sound sensor picks up the baby’s cries and initiates the

proper reactions, a temperature sensor keeps an eye on the surrounding conditions to guarantee the baby’s comfort. Furthermore, a wet sensor alerts the caregiver if there is any moisture in

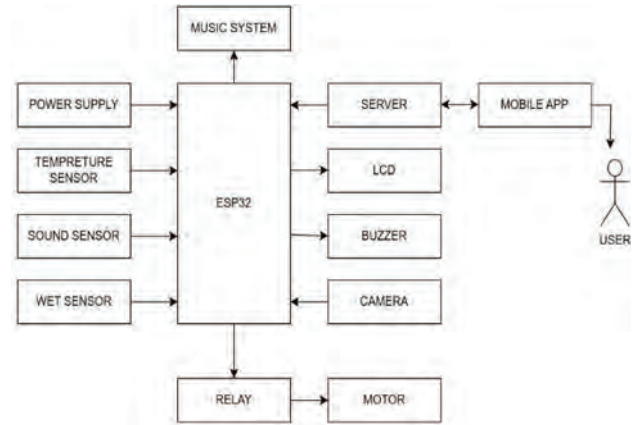


Fig. 1: Cradle System Block Diagram

the cradle, such as from a diaper. A buzzer for aural notifications, a music system to play calming music, and a motor to rock the cradle are among the outputs. Real-time information is shown on an LCD, and live video monitoring is provided by a camera.

Through a mobile app, the solution enables caregivers to remotely monitor and operate the cradle. It uses a relay to automate high-power components, such as the motor, and provides real-time monitoring, alarms, and smooth communication for effective baby care [6][7].

Flowchart

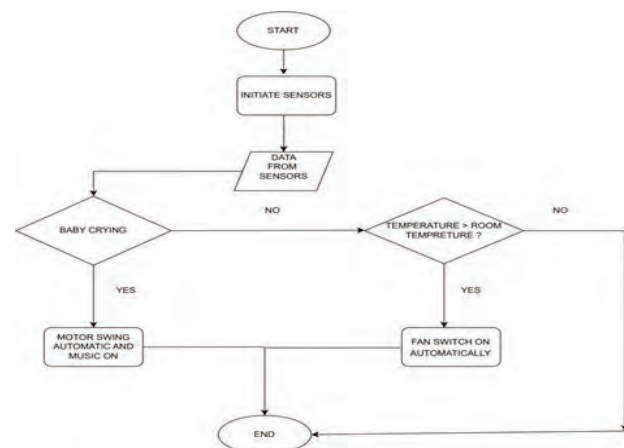


Fig. 2: Flowchart

An automated newborn care system is depicted in this flowchart. It starts by activating sensors to gather data.

When a baby cries, the device starts a motor swing and plays music. If the room temperature increases above a specified threshold, the fan automatically activates. When specific conditions are not met, the system terminates, but the process continues[8].

Circuit Diagram

The circuit diagram created for the project using Proteus software is seen in Figure 3.3. To operate the system, the Arduino Uno controller's coding must match the completely connected circuit.

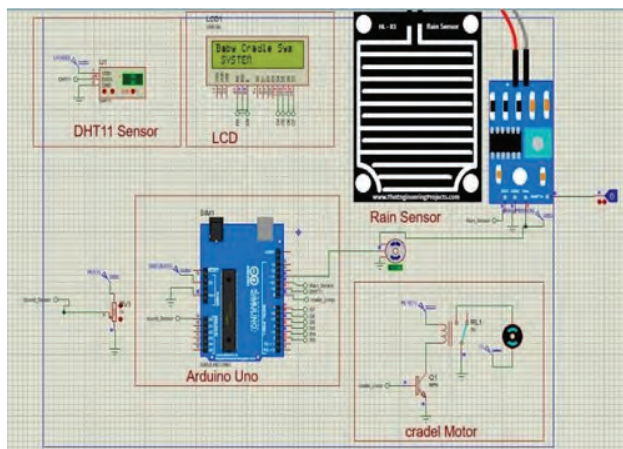


Fig. 3: Cradle System circuit diagram

Methodology

- Vital Signs Monitoring: Continuously track the baby's vital signs.
- Cry Detection: Use a sound sensor to trigger cradle rocking when the baby cries.
- Wet Mattress Alert: Implement a dry/wet sensor to send SMS alerts to parents if the mattress is wet.
- Temperature Control: Activate a fan using a temperature sensor to maintain comfort.
- Music Activation: Play soothing music automatically when the baby cries.
- Parental Communication: Utilize Wi-Fi modules for real-time alerts to parents.

Features of the Parent's Mobile Application

- Live streaming: Users can monitor the baby's activity at any moment.
- Swing cradle: Users can swing the cradle in response to the baby's screams.

- Temperature and humidity: Users can keep an eye on the temperature and humidity of the baby's surroundings in real time.
- Alerts: Users will be informed of a range of unusual activity.

Sensors And Components

DHT11 Sensor

It measures the temperature of the surrounding air using a thermistor and the moisture content using a capacitive humidity sensor. An Analog to Digital Converter (ADC) chip is not required because it transmits digital readings via data pin. The main issue with this sensor is that it transmits data every two seconds, notwithstanding its ease of use. Many online publications explain how to connect a DHT11 sensor to an Arduino, making it simple to connect this sensor to any Arduino board.

Rain Sensor

When a drop of rain falls through the wet board, it can serve as a switch and be used to gauge the amount of rainfall. The module features a rain board, a potentiometer for sensitivity adjustment, an LED power indicator, and a separate control board for convenience. The analog output is used to detect drops in the amount of rainfall. The LED is attached to a 5V power source and will turn on when the DO output is high and there are no raindrops on the induction board. When a small amount of water is dropped and the DO production is low, the switch indication will turn on. The output level goes back to its starting point after the water droplets are eliminated.

Sound Sensor

The KY038 is an extremely sensitive sound detection module that can produce both digital and analog signals. This module is compatible with the Arduino. This module even allows you to measure ambient sound intensity. The majority of digital sound sensor modules only provide digital output, such as whether or not sound is present. However, the analog output voltage that this sound sensor module offers is likewise directly proportional to the level of background noise.

The Voice Module

The Voice Record Module is based on a multiple-message record/playback device called the ISD1820. It offers genuine single-chip speech recording, no volatile storage, and a playback duration of 8–20 seconds. The recorder's

total time is 20 seconds, and the sample size is 3.2k. This module is very easy to use and can be controlled by a push button on the board or a microcontroller such as an Arduino, STM32, Chip Kit, etc. These make it simple to record, play back, repeat, and perform other tasks.

LCD

It can be controlled by a 4- or 8-bit computer to power a liquid crystal display with dots. With its display RAM, character generator, and liquid crystal driver, this controller/driver includes all the internal functionality required to run a dot-matrix liquid crystal display, making it easy to connect with a simple system.

Servo Motor

The SG90 Micro Servo Motor, a small, light server motor with a high output power, is used in this system. For a total of 180 degrees, the servo can rotate 90 degrees in two opposite directions. The cradle swinging action is provided by this. It does the same tasks as regular servos while being smaller. To operate these servos, a servo code or library is required.

ESP 32

The ESP32 is a low-power, highly integrated Wi-Fi and Bluetooth chip for IoT and mobile applications. It features advanced power management, reducing energy use in low-duty cycle tasks. The chip integrates an antenna switch, power amplifier, and other components, minimizing external parts. It supports peripherals like touch sensors and SD card interfaces. The ESP32 development board includes breakout pins, a 3.3V regulator, and USB-to-TTL for easy programming. With power consumption as low as 5 μ A, it's ideal for battery-powered devices.

RESULTS AND DISCUSSION

The outcomes of the simulation or experimentation should be grouped or arranged in a logical and orderly manner. Only the most pertinent findings ought to be included in this section.

The results in this part are presented in textual form, emphasizing the key findings. Figures can be utilized for clarity and ease of understanding. This chapter analyzes the system that uses a DHT11 sensor to monitor the temperature and environment and a sound sensor to detect noise from the baby. Several tools and components were used in the project, including an Arduino Uno, servo motor, sound sensor, moisture sensor, and DC motor.

Figure 4 shows a complete prototype of the project.

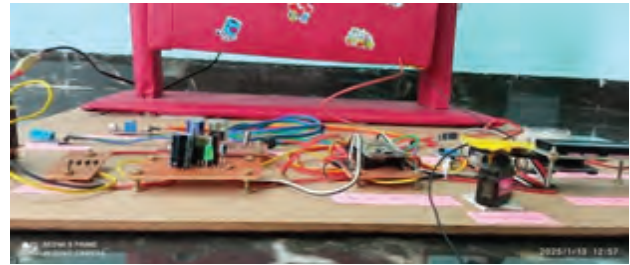


Fig 4 : The Cradle System in front view

Analysis of sound detection

The responses of the sound sensor both before and after noise detection are displayed in Table 1. The sensor's LED stays off (green circle) when no sound is detected. The LED turns on (blue circle) and signals the server when it detects sound. The links attached to the carriage are then actuated by the motor shaft, moving the bed at a constant speed.

Table 1: Sound comparison

Parameter	Frequency range
Female baby S1	2100
S2	2143
S3	2210
Male baby S1	2870
S2	2800

In order to monitor environmental factors including temperature, humidity, sound, and rain, this parent application was created for a smart baby cradle project. Parents can receive real-time notifications such as "Moisture Detected" or "Baby is Crying" to let them know about important happenings. To guarantee the baby's comfort and security, the dashboard shows sensor data visually. It also records notifications so that the system's activities may be monitored.

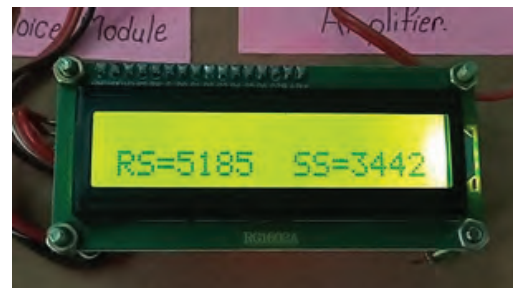


Fig. 5 : Parent Application view

The above Figure 5 of parent application is indicating the Temperature & humidity values as well as Sound sensor values.

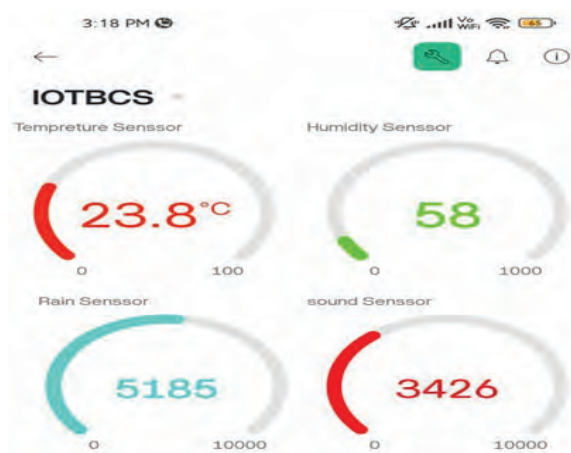


Fig. 6 : Notifications Popups

The above Figure 6 of parent application is indicating the alert message for baby crying and moisture is detected means baby cradle is wet.

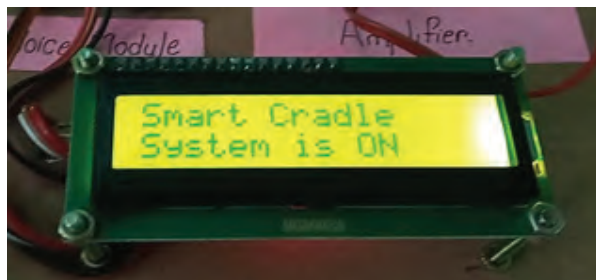


Fig 7 : Smart Cradle System On

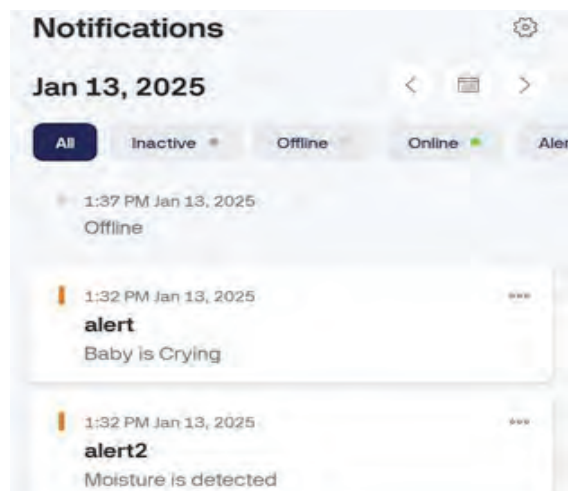


Fig. 8 : Rain And Sound Sensor Alert

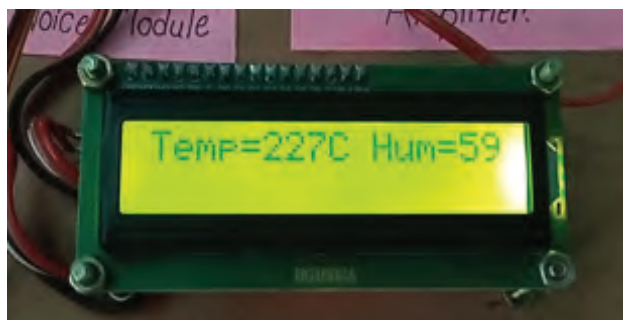


Fig. 9 : Temperature and Humidity Alert

CONCLUSIONS

The smart baby cradle system is designed to make newborn care easier, particularly for caregivers who work. Its numerous sensors allow it to measure the moisture level of the mattress, detect the baby's screams, change the temperature, and automatically swing the cradle as needed.

Additionally, the cradle features a built-in camera monitoring system that lets parents or other caretakers watch the baby live on video. This guarantees that the infant's safety and comfort are continuously observed. The clever features of the system lighten the strain for nurses and parents, freeing them up to concentrate on other duties while maintaining comprehensive care. It provides a dependable answer for contemporary child care with its affordable design and easy-to-use interface.

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Emotion Recognition Based On Text Using Artificial Neural Network for Natural Language Processing

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ABSTRACT

Emotional reconciliation is a fascinating yet complicated problem. In today's age of artificial intelligence, machines are programmed to mimic human behaviour and operate accordingly. Affect computing is concerned with the research of this topic. There are several forms of communication that individuals use to express their sentiments, opinions, and feelings. Feeling, mood, and emotion are separate concepts that are frequently used in conjunction. Emotion can be detected by facial expressions, speech, biomedical signals etc. Nevertheless, recognizing emotions in text can be difficult as clues such as tonal stress facial expression, tone, and so on are missing in contrast to speech. In this work we propose a simple and effective system to deal with emotion recognition from text, comments using simple Neural Network using an embedding Layer and a Dense Network. Our model is built sequentially layer-by-layer using the Sequential API. It is a simple feed forward neural network. From the performance of model Accuracy = 81% is achieved for approximately 2000 samples. The dataset we have used is class imbalance[16], particularly for surprise and love emotion causing reduction in average accuracy

KEYWORDS : *Natural language processing, Semantic analysis emotion, Neural network.*

INTRODUCTION

Text-based emotion categorization is a developing field of NLP, or natural language processing, is the study of recognizing and classifying emotions in textual data. nowadays, the majority of communication occurs on social networks through numerous social networking applications, including Twitter, Facebook, Instagram, WhatsApp, and others. The most popular media for sharing our thoughts, feelings, and sensations is text. Social media

Communication takes the form of text, images, audio, and video, all of which contain information and use up bandwidth, memory, and space.[1]. Therefore, it becomes crucial to comprehend the emotion of the person delivering the message. Humans naturally have the ability to understand their emotions, feelings, and moods, yet this ability is largely vague. NLP (natural

language processing), linguistic and computational methods, which assist computers in comprehending and producing textual and spoken human-computer interactions, are still unclear. NLP being the subset of Deep Learning is still to be explored in large context. Its goal is to create a model for several processes, including sentiment, perception, beliefs, and emotions[2]. Paul Ekman, worked largely on facial expressions and emotion recognition; yet, text-based emotion research has been influenced by his groundbreaking studies on basic emotions of anger, contempt, fear, happiness, sorrow, and surprise. Researchers often rely on Ekman's taxonomy of emotions when designing models for text-based emotion classification. There are significant challenges involved in the area of Text based emotion recognition. Language and meaning of each word, words can have multiple meanings, and the tone or intent may vary from language to text.

Emotion are subjective and context dependent making it difficult to consistent labeling. low datasets and effective tools are another limitation in this area. Emotional understanding varies by individual and culture, highlighting the necessity for inclusive databases. There are various approaches and techniques available to cater different challenges in this area are Rule-Based Methods which is traditional and compared to machine learning less effective method. use of machine learning has significantly enhanced the performance of of rule based method. by using different machine learning models efficient results can be obtained in text based emotion recognition .advanced deep learning techniques are another approach for emotion recognition using text. Text-based emotion classification offers an ideal environment for research, with the potential to positively impact a variety of areas of study.

LITERATURE REVIEW

Several researches have utilized different ways to identify emotions in text[2]. [1–5], from which one can guess the effectiveness of each methodology and pros and cons of the individual's techniques. Amal et al.[1] indicates that machine learning-based text emotion classification techniques are more accurate than current methods. This effort attempts to increase emotion recognition accuracy using advanced machine learning algorithms. the work also compared previous result of logistic regression and K-NN classifiers, for text emotion recognition task in hand achieving average accuracies of 64.08% and 67.08%, Decision Tree Classifier has the best average performance in terms of efficiency, sensitivity and f1 score at 84.7%, 74.2%, and 94.1% respectively [1].The Support Vector Classifier, Linear SVC, and Random Forest Classifier are proposed as emotion detection methods in this work. It employs a dataset with six emotional categories and emphasizes the significance of preprocessing and feature extraction. The study advances the area by offering a novel way to categorizing emotions from text that makes use of extensive syntactic and semantic analysis.

Santosh Kumar Bharti et al.[2] authors offer an innovative approach that combines Deep learning and machine learning methods to improve emotion identification in text. Deep Learning Techniques are used namely Support Vector Machines (SVM), Convolutional Neural Networks (CNN), and Bidirectional Gated Recurrent Units (Bi-GRU).the model is trained on three distinct datasets: Emotion-Stimulus, WASSA, and ISEAR the collective

dataset) has over 14,500. The six emotions—disgust, fear, surprise, anger, and sadness—are indicated on text sentences. Several processes are taken to clean raw data and prepare it for analysis e.g. Tokenization, Removing common words Emoji Conversion, Stemming and the lemmatization. The model employs methods like Term Frequency-Inverse Document Frequency (TF-IDF) to detect key terms in the text. Converts words into numerical vectors that represent their meanings in a way that machines can understand . The hybrid model achieved an accuracy of 80.11%, which is better than previous methods. The study introduces a novel way to understanding emotions in text that combines various both deep learning and machine learning techniques, resulting in promising accuracy and effectiveness.

Long-Sheng Chen et al. work focuses on Research Article on Sentiment Classification in Blogs ,as we know Blogs are popular venues where people express their ideas and emotions over many topics, including products .Understanding the sentiment (positive or negative thoughts) in blog postings is critical for businesses because bad feedback can ruin their reputation .the aim of this work is sentiment classification to quickly and accurately identify the emotions expressed in blog posts .here are two main approaches to sentiment classification ,Semantic Orientation Indexes (SO Indexes),Machine Learning (ML) Techniques. The authors offer a new strategy that combines the strengths of both SO indexes and machine learning techniques using a neural Network. The neural network uses the results of the SO indexes as inputs to classify sentiments more successfully and fast. Back-Propagation Neural Networks (BPNs) are noted for their capacity to learn and adapt. To validate their strategy, the researchers collected data from several blogs and product reviews .The experimental results shown by author indicate that the suggested approach is outperforming existing neural networks and semantic orientation indexes.

Neural network

Neural networks have transformed text-based emotion recognition by utilizing their ability to autonomously learn features and patterns from unstructured text input as shown in fig 1.

METHODOLOGY

To perform classification tasks of discrete emotion recognition based on text, comments it is necessary to import essential libraries and modules to implement a text-

based machine learning pipeline for emotion recognition or sentiment analysis. Text Vectorization is achieved through a preprocessing layer for converting raw text into a numerical format suitable for machine learning models. fig.2 shows the samples from dataset used. Total 6 basic emotions are used as per dataset [16] provided namely, anger, fear, joy, love, sadness, surprise. As shown in fig.3 our dataset contains the number of text with discrete emotion labels, the number of text for joy emotion and sad emotion are comparatively more than that of surprise, fear, anger emotion. Imbalanced dataset generally not advisable for machine learning techniques may lead to inaccurate results. Our sequential model to classify emotion is a neural network for text classification, targeting a task emotion recognition using a simple feedforward neural network.

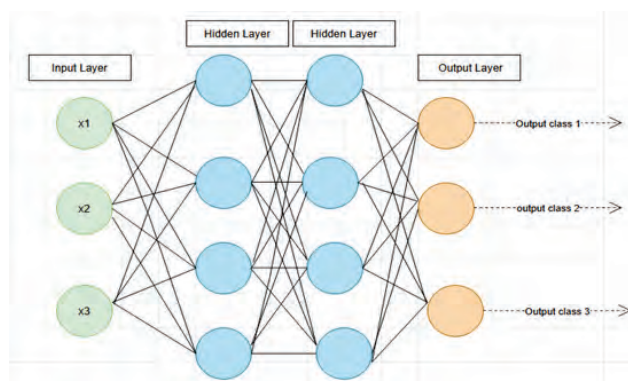


Fig. 1. Simple Architecture of Neural Network [created using draw.io]

	Text	Emotions
0	i can go from feeling so hopeless to so damned...	sadness
1	im grabbing a minute to post i feel greedy wrong	anger
2	i am ever feeling nostalgic about the fireplac...	love
3	i am feeling grouchy	anger
4	ive been feeling a little burdened lately wasn...	sadness

Fig. 2. Samples of dataset [image: display of data frame during experimentation]

RESULTS AND DISCUSSION

As shown in the fig 4 .below the results obtained for various classes, for particularly the algorithm performs well in predicting the “joy” emotion, correctly classifying

619 of 676 cases. This shows that the model is particularly good at identifying and discriminating joyous emotions. The algorithm also exhibits reasonable accuracy in predicting “sadness,” properly categorizing 503 out of 551 occurrences. This demonstrates a reasonable capacity to recognize and differentiate sad feelings. There is some confusion between “fear” and “surprise.” The model incorrectly labels 23 “fear” cases as “surprise,” and 16 “surprise” instances as “fear.” The model also shows some confusion between “anger” and “love.” Since our dataset has an imbalanced class distribution, with some emotions being more frequent than others this leads to overall accuracy of 81%. As shown in fig.5 the model appeared to be learning effectively given the training data, as shown by lower loss and higher accuracy. Fig.4.shows the performance of LSTM model for our dataset ,the results obtained from LSTM model though look promising ,but since the model shows significant signs of over fitting these results cannot be considered.

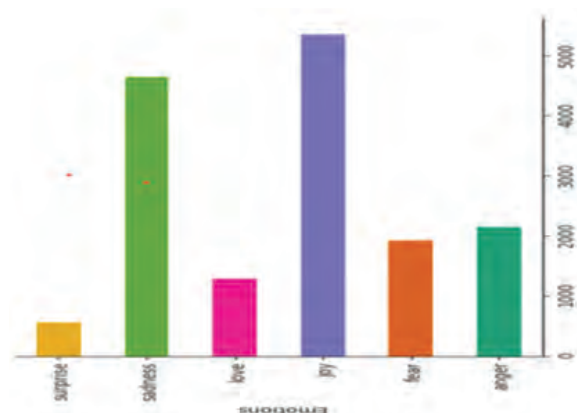


Fig. 3. Total number of text count vs number of emotion plot

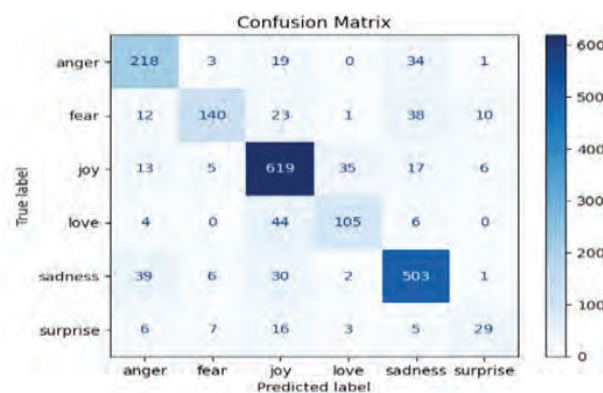


Fig. 4. Confusion matrix for six classes of emotion using Neural Network classifier

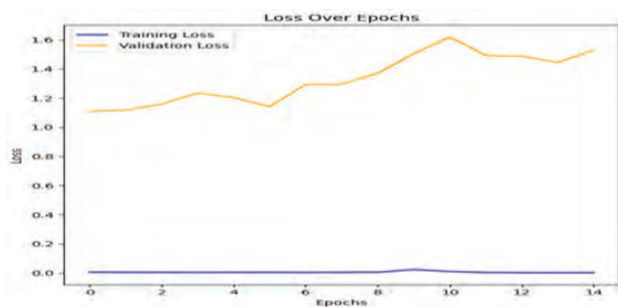


Fig. 5. Plot of Loss over Epochs

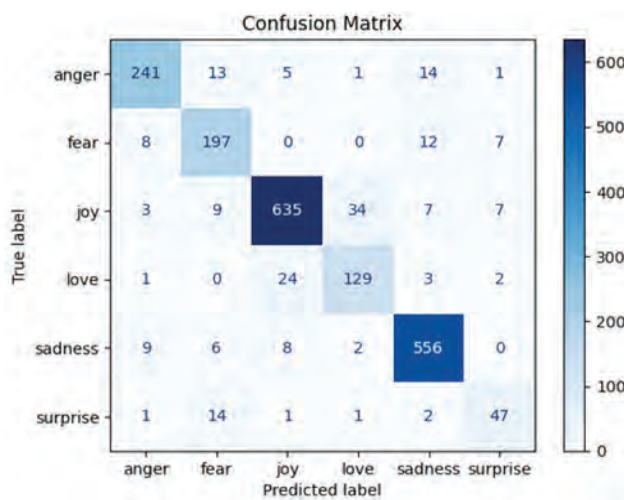


Fig. 6. Confusion matrix for six classes of emotion using LSTM Classifier

CONCLUSIONS

From the work carried out, it is observed that for effective discrete emotion recognition from text using neural networks, our model is performing good for emotions which are joy and sadness. our model is decent in performing recognition tasks for anger classification. our model is inaccurate in some cases of fear and surprise. modifying model for better threshold and balancing dataset may further improve the result of accurate classification. Compared to traditional method of text emotion for various applications deep learning techniques outperform. Data augmentation can be used to further balance the dataset. Investigating novel traits that may be more informative in discriminating between emotions such as “fear” and “surprise” or “anger” and “love.”

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A Comprehensive Review of IoT Gateways and Clouds

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ABSTRACT

This paper provides a comprehensive review of IoT gateways and the Cloud. A gateway is an internet-connected component that joins two separate networks with different communication protocols. It also serves as an interface or “Gate” across networks, enabling every message to travel through it before getting forwarded. The gateways may handle both LAN and WAN connections. The gateway serves as a “translator” between two systems with differing protocols for communication, types of data, or design principles. It might include a computer server, a router, firewall, or any other type of networking device that allows transport to enter and exit the network’s infrastructure. The data via gateways is directed to the Internet of Things (IoT) cloud. Cloud services include quick database servers, on-demand computer facilities and memory. It additionally makes it simple to develop software for processing and analyzing information collected by many different IoT devices. IoT clouds provide on-demand, affordable vast scalability, enabling businesses to take advantage on IoT’s huge potential without having to construct the foundations and related functions from the bottom up. In this work, different kinds of IoT gateways and clouds are briefly discussed and explored.

KEYWORDS : *IoT, Gateways, Clouds, Protocols, Communication network, LAN, WAN.*

INTRODUCTION

One of the most important technologies in industry 4.0 is the Internet of Things (IoT), which aims to create a network of countless objects that can dynamically interact, identify, sense, participate to decision-making processes, and share information on a global scale via the Internet.

A gateway for the IoT is an electronic device that links IOT to different network or to the internet. It is essentially an element of software or hardware that enables devices connected to the internet (IoT) to link to the internet to interact among additional things or applications. Data sorting, protocol interpreting, safety, and management of networks are among the functions that IoT gateways can do. They frequently offer administration of devices, information processing and evaluation, and integration with cloud-based applications.

Each system has an obstruction that merely allows interaction among gadgets that are physically linked to it. As a consequence, if an internet connection requires interaction with gadgets, node locations, or systems outside of that boundary, it must have gateway capabilities.

The gateway is located at the network’s boundaries and processes any information sent within and outdoors.

The gateways are protocols translators that can function within any layer of the OSI (open systems interconnection) concept, allowing two different protocols to interact with one another.

LITERATURE REVIEW

The creation of the Internet of Things began in 1982 with the connection of a vending machine to the internet, followed by Mark Weiser’s concept in 1992, RFID, and so on.

A comprehensive assessment of the literature on IoT gateways in general and smart gateways in particular has been provided by Gunjan Beniwal et al. [1]. It examined works released between 2011 and July 2021, representing the last ten years. Based on well-defined criteria, 67 articles were selected for in-depth analysis out of 2347 papers in this review's systematic evaluation of the literature strategy.

In the current modern technology sector, Kamalrulnizam Bin Abu Bakar et al. [2] have thoroughly analyzed the Internet of Things and its rapid advancement.

Innovative methods for running low-power Internet of Things networks have been investigated by Moussa Aboubakar et al.[3]. To effectively manage IoT low-power networks, the authors identified a few requirements and suggested classifying existing approaches into five categories: SDN-based frameworks, cloud-based frameworks, machine learning-based frameworks, semantic-based frameworks, and network management protocols for IoT low-power networks.

Eisha Akanksha et al. [4] have provided a comprehensive review of modern IoT application architectures, as well as how one common IoT reference architecture may be used as a model for evaluating diverse Internet of Things solutions.

The Internet of Things has been discussed by Luigi Atzori et.al. [5]. The combination of various technologies and networks for communication is the major enabler behind this promising concept.

TYPES OF IOT GATEWAYS

In the industrial sector, gateways have no criteria aside from specific to the brand. Gateways can be usually classified depending on functionality, efficiency, speed, and usefulness. The unidirectional gateways allow data to go in only one direction, whereas bidirectional gateways permit data to travel in both directions[6].

Internet of Things gateways vary in shape and dimensions, and every has its own set of capabilities and objectives [7]–[9].

Cloud-based Gateway

A cloud-based gateway is a type of networking gateway that runs in a cloud environment and offers an encrypted link across a local network and the global web.

Edge Gateway

IoT Edge gateways, additionally referred to as devices at the edge, are network-related devices which reside at the edge of the network and serve as a link among IoT devices and the cloud.

Protocol Gateway

An IoT protocol gateway is a component of both hardware and software that links many devices to the global web. It allows devices to connect and interact with each other over the internet using a variety of communication protocols.

Security Gateway

IoT security gateways are software or hardware systems that provide safety measures for internet-connected devices and networks. It functions as a bridge between IoT devices and the Internet.

Application Gateway

An IoT application gateways is a software or hardware component that links IoT devices to cloud-based tools or applications via which they interact. It usually serves as a translator, translating data gathered by IoT gadgets into a language that service providers can understand.

Mobile Gateway

A mobile gateway for IoT links IoT devices to networks or the global web, typically over cellular or wireless communications protocols. IoT mobile gateways offer a dependable and secure technique of sending information collected by IoT gadgets to the cloud.

Home Gateway

A home gateway is a network equipment that connects to the Internet from a network within the home (LAN). It allows residential or tiny workplace equipment to link to an internet service provider (ISP) to utilize the internet.

Medical Gateway

A medical gateway, also known as a medical information gateway, is a secure technological structure that enables various health groups, infrastructure, and professionals to exchange digitized health information.

Network Gateway

A network gateway is an electrical device that connects several networks by converting protocols for communication. Network gateways are designed to translate interactions among protocols.

Internet-To-Orbit Gateway (I2O)

This approach enables Internet users all around the globe to have access to technological and scientific data collected from space. Direct interaction with things in orbit was formerly restricted to sophisticated government agencies such as NASA.

VoIP Trunk Gateway

It links Plain Old Telephone Service (POTS) equipment, such as telephone lines and fax machines, to the VoIP network to provide quicker information transmission. A trucking gateway, often known as a PSTN gateway, is an equipment that links VoIP to the public switched telephone network (PSTN).

Table. 1. Summary of IoT Gateways[7]–[13]

Gateways	Functions
Network Gateway	It joins two separate networks with different protocols.
IoT Gateway	IoT gateways incorporate sensor data from destinations within the surroundings.
Cloud Gateway	It's a web platform that converts memory demands into numerous storage in cloud profiles.
Internet-To-Orbit Gateway (I2O)	It links devices that can access the internet to satellites in orbit and spacecraft.
VoIP Trunk Gateway	It connects POTS (plain old telephone service) devices, such as telephone lines and fax machines, to the VoIP network to enable quicker information transmission.

TYPES OF IOT CLOUDS AND CLOUD PLATFORMS

Cloud computing is a revolutionary technology that is changing the way people archive, availability, and evaluate data. This simply refers to the supply of computer hardware via the web, which include storage spaces, databases, programs, and apps. [14].

Types of Cloud

The five primary categories of cloud computing are private clouds, public clouds, hybrid clouds, community clouds, and multi-clouds. Figure 1 depicts several sorts of clouds.

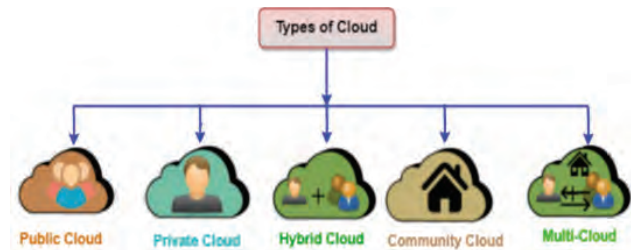


Fig. 1: Types of cloud

Public Cloud

Cloud Service Providers (CSPs) manage and run hardware and software in the public cloud. The CSP controls the foundational facilities ensuring that facilities are available and adaptable to clients.

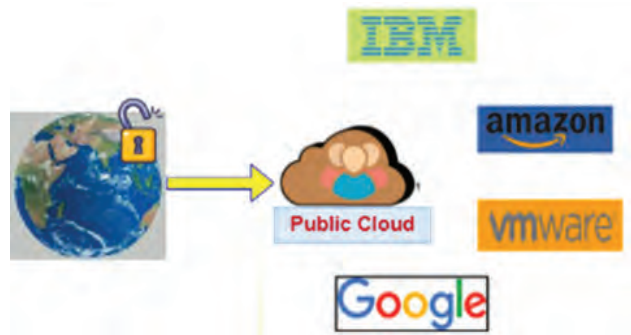


Fig. 2: The concept of the public cloud

Private Cloud

Corporations utilize it to build and operate data centers either on their own or via another organization. It can be implemented using open-source platforms like OpenStack or Eucalyptus. VMware vSphere, OpenStack, Microsoft Azure Stack, Oracle Cloud at Customer, and IBM Cloud Private are some other examples. Figure 3 depicts the private cloud paradigm.

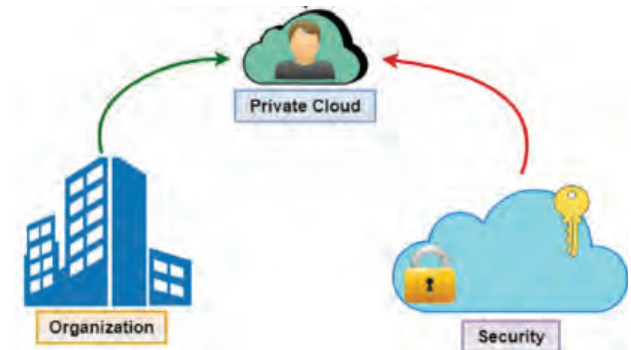


Fig. 3: The idea of private clouds

Hybrid Cloud

The hybrid cloud incorporates both public and private clouds. The hybrid cloud is generally secure because services in the public cloud can be accessed by anybody, whilst those in the private cloud are only accessible by employees of the organization.

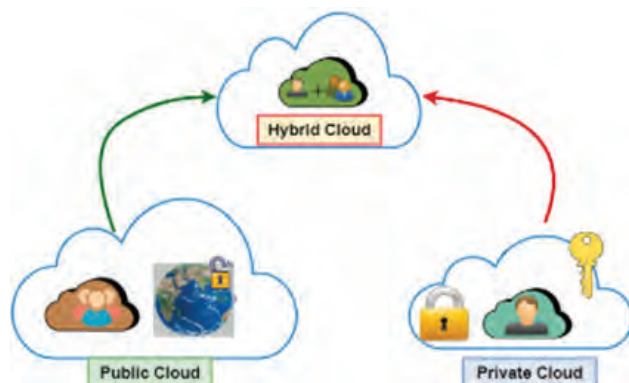


Fig. 4: The concept of the Hybrid cloud

Community Cloud

A community cloud enables individuals from different groups to use services and tools to exchange knowledge among both the organization and particular groups. The facility is owned, regulated, and managed by several community organisations, another organization, or a mix of the two.



Fig. 5: The Framework of the Community Cloud

Multi-Cloud

Multi-cloud is an internet-based computing technique in which enterprises use multiple providers of cloud services or ecosystems to meet their processing requirements. It entails distributing their workloads, programs, and analytics among multiple cloud platforms, especially public, private, and hybrid ones.



Fig. 6: The concept of the multi-Cloud

IoT Cloud Service Models

Cloud service models are categorized into three distinct categories:

IaaS (Infrastructure as a Service)

IaaS is also known as Hardware as a Service (Haas). The primary advantage of using IaaS is the fact that it enables customers to avoid the costs and problems involved with managing and owning servers on their own.

PaaS (Platform as a Service)

The PaaS cloud computing environment enables developers to design, assess, run, and manage apps. Google App Engine, Magento Commerce Cloud, AWS Elastic Beanstalk, Windows Azure, Heroku, Force.com, Apache Stratos, and OpenShift are among the choices.

SaaS (Software as a Service)

The word “on-demand software” encompasses SaaS. The previously mentioned software’s applications are hosted by a cloud service supplier. Subscribers are able to use these applications via the internet. Examples include Cisco WebEx, Salesforce, Big Commerce, Google Apps, Dropbox, Zendesk, Slack, and GoToMeeting and many others.

IoT Cloud Platforms

IoT cloud services offer a variety for interaction options, with an emphasis on extensive network connectivity. Users have access to cloud computing services through a range of gadgets, like tablets, smartphones, and laptop computers.

Application Development

KAA

KAA (<http://www.kaaproject.org/>) is a comprehensive freely available middleware platform for Internet of Things

(Apache License 2.0) for creating intelligent associated and from beginning to end IoT solutions

Temboo

Temboo (<https://temboo.com>) is a private cloud-based environment for creating code for software. It reduces the cost of wiring and coding both software and hardware, resulting in fewer hours spent developing and promoting an IoT solutions. [15][16].

Device management

These IoT systems specialized in managing and controlling devices in the manner of digital processing modules (Arduino, Raspberry Pi, etc.) and analog electrical devices (industrial motors, rotors, and household gadgets).

SeeControl IoT

SeeControl (<http://www.seecontrol.com>) is a standalone Platform as a Service-oriented Internet of Things cloud computing service that focuses on device-management communication.

SensorCloud

SensorCloud (<http://www.sensorcloud.com>) is a personalized IoT cloud providing Platform as a Service for gathering, viewing, observing, and interpreting data gathered from wired or wireless sensors.

System management

These internet of things platforms handle system-related tasks, which makes them essential for developing an appropriate framework.

Ayla's IoT cloud fabric

Ayla IoT Fabric (<https://www.aylanetworks.com>) is an inexpensive, enterprise-class PaaS-based solution that allows manufactures to link any device to the web.

thethings.io

thethings.io (<https://thethings.io>) platform provides an extensive backbone solution for IoT devices and APP developers, along with an easy and customizable API. thethings.io is compatible with any device which utilizes the web sockets, HTTP, MQTT, or CoAP protocols, irrespective of hardware.

Heterogeneity management

These IoT cloud-based services allow communication and connection across systems, solving many challenges [16] [17].

Arrayent Connect TM

Arrayent (<http://www.arrayent.com>) is an Internet of Things platform that links products from major brands such as Whirlpool, Maytag, and First Alert, among others, to value-added smart devices and internet-based apps.

Open Remote

Open Remote (<http://www.openremote.co>) is a free IoT middleware platform that allows individuals to link to any gadget or protocol layout using existing tools like as iOS, Android, or web browsers.

Data management

These IoT platforms can share data-related processes and duties, giving users comprehensive details about the current situation.

Arkessa

Arkessa (<http://www.arkessa.com>) provides interaction, tracking, oversight, and administration for IoT devices and businesses. Arkessa's goal is to assist businesses utilize IoT to increase income by boosting customer satisfaction and using information gathered by outside sources.

Axeda

Axeda (<http://www.axeda.com>) provides a cloud-based Internet of Things (IoT) service that handles connected devices and equipment, in addition to developing M2M services.

ThingWorx

ThingWorx (<https://thingworx.com>) is a popular private cloud platform that allows for decisions based on information.

Analytics

It gives a solution to utilize cloud-based analytics tools for statistical analysis.

InfoBright

InfoBright(<https://www.infobright.com/index.php/internetof-things>) provides a statistical schema-knowledge Grid framework (IoT-based analytical database platform) that allows businesses to store, evaluate, and respond on machine-generated information.

Jasper Control Center

Jasper Control Center (<https://www.jasper.com>) provides an exceptionally adaptable platform that can be adjusted

to individual operating requests, corporate structures, and requirements across industries and regions worldwide.

Deployment management

It comprises designing, developing, building, testing, and implementing innovative software and hardware components in a real-world environment.

Echelon

Echelon (<http://www.iiot.echelon.com>) is a cloud service that enables the Industrial Internet of Things. It contains microchips, protocol stacks, hardware components, communications user interfaces, and administration software for creating devices for peer-to-peer communities and apps.

Monitoring management

These IoT cloud platforms perform an important role in network disaster mitigation and network efficiency maintenance.

AerCloud

AerCloud (<http://www.aeris.com>) serves as a cloud-based platform that collects, organizes, and analyzes sensor data for IoT and M2M activities.

ThingSpeak

ThingSpeak (<https://thingspeak.com>) serves as an open IoT information platform that uses public cloud technology. ThingSpeak offers real-time data collection, assessment, and activation through an Open API.

Visualization

These IoT cloud systems offer powerful and statistical visual representation capabilities to aid with system comprehension.

Plotly

Plotly (<https://plot.ly>) is a well-known public Visualization of data cloud service. Plotly provides data storage, representation in the workplace, and analytics solutions for community, expert, and corporate use cases, especially IoT applications.

GroveStreams

GroveStreams (<https://www.grovestreams.com>) is a popular public data visualizing cloud. The range of time spans from one second to one year. Types of data supported include short, integer, long, text, geo-coordinates, and time.

Research

These IoT cloud platforms enable academicians to evaluate cloud-centric innovations using a simulation, reducing the expense of real-world deployment. This decreases the likelihood of financial loss along with time to market.

Microsoft research Lab of Things

Microsoft's Lab of Things (<http://www.lab-of-things.com>) is an open Internet of Things infrastructure intended for educational use.

IBM IoT

The IBM IoT cloud platform (<https://internetofthings.ibmcloud.com>) is intended to securely and easily connect gadgets such as independent chips, intelligent appliances, and advanced manufacturing services.

CONCLUSIONS

In this paper, we present a comprehensive assessment of IoT gateways and clouds. The potential application of the Internet of Things (IoT) is vibrant and dynamic. Numerous organizations and companies are currently embracing IoT. It is gradually acquiring importance in everyday life and appears everywhere around us. The Internet of Things is expected to dramatically revolutionize various industries, including manufacturing, supply chain management, health care, transportation, and agriculture.

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Optimization Method for Abnormal Heart Sound Detection: A Review

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ABSTRACT

This study offers a thorough analysis of an optimization technique for identifying irregular cardiac rhythms. The introduction of machine learning (ML) and deep learning (DL) techniques has led to notable breakthroughs in the field of medical diagnostics. Specifically, the use of audio signal processing to identify irregularities in cardiac sounds has great potential to enhance patient outcomes and diagnostic precision. The goal of this research is to harness these technical developments to improve heart disease detection, which is a crucial component of managing cardiovascular health. By integrating ML and DL methodologies with feature fusion, transfer learning, and multimodal data integration, this research aims to develop a robust and comprehensive approach to abnormal heart sound detection. Such advancements have the potential to revolutionize clinical practice by offering more accurate, efficient, and accessible diagnostic tools for identifying cardiovascular conditions early and effectively. This study falls into the field of cardiovascular health, using modern machine learning (ML) and deep learning (DL) techniques to classify and identify heart disorders from acoustic data.

KEYWORDS : Machine learning, Deep learning, Cardiovascular diseases, World Health Organization, CNNs, RNNs, ECG, MRI.

INTRODUCTION

Cardiovascular diseases are a leading cause of mortality worldwide, making early and precise diagnosis essential. Auscultation, a traditional diagnostic method, relies on physicians' expertise to interpret heart sounds. However, technological advancements have introduced automated approaches that enhance diagnostic accuracy. This paper reviews the latest developments in abnormal heart sound detection, emphasizing optimization techniques that improve performance. Improving patient outcomes and lowering the disease burden depend heavily on early CVD detection and diagnosis. Early detection of cardiovascular irregularities enables timely intervention, which can lower the risk of consequences like heart attacks

and strokes, alleviate symptoms, and stop the progression of the condition..

Conventional diagnostic techniques for identifying heart conditions frequently depend on physical examination, clinical evaluation, and common imaging modalities including cardiac magnetic resonance imaging (MRI) and echocardiography. While these approaches provide valuable information, they have certain limitations. For instance, they may lack sensitivity and specificity, leading to missed diagnoses or false positives. Additionally, traditional diagnostic methods may be time-consuming, costly, and require specialized expertise and equipment, posing challenges for widespread implementation, particularly in resource-limited settings. The study's

goals are laid out in the introduction, which highlights the necessity of advanced techniques to improve diagnostic precision and effectiveness. It also emphasizes how the suggested method is multidisciplinary, combining developments in machine learning, deep learning, feature fusion, transfer learning, and multimodal data integration to address the challenges of cardiovascular health assessment.

LITERATURE REVIEW

Recent research efforts have focused on investigating novel approaches in cardiovascular diagnostics, motivated by the urgent need for more precise, effective, and easily accessible techniques for identifying and treating heart conditions. In this sense, DL and ML approaches have become effective instruments for deciphering intricate biomedical data. Offering promising avenues for enhancing cardiac diagnostics. With an emphasis on the use of ML and DL approaches in the analysis of irregular heartbeat audio data, this literature review gives a detailed summary of recent advances in the diagnosis of cardiovascular disorders.

Yadav et al.[15] suggested a unique architecture for detecting heartbeat sounds in the elderly that uses convolution neural network models and multimodal gates for recurrent units. Their research proved the accuracy of DL models in reliably identifying aberrant heart sounds, underlining the potential of DL approaches for specific to age cardiac diagnosis.

Malik et al.[16] created a several classifications artificial neural network model that detects aberrant cardiac audio signals. Their study showcased the utility of neural network architectures in classifying diverse types of cardiac abnormalities, underscoring the versatility of DL techniques in cardiovascular diagnostics.

Regarding wellness surveillance, Nandi et al. [17] assessed how well ML strategies performed on system-on-chips in wearable.

Pradhan et al.[18] used wavelet packet-based segmentation and ML models to study the influence of sound stimuli on cardiac electrophysiological in young people.

Sheela et al.[19] proposed a mixed DL approach integrated with the Internet of Things (IoT) for monitoring human activities using wearable sensors. While not specific to heart disease detection, their study highlighted the integration of DL algorithms with wearable sensor technology for

real-time health monitoring, which could be leveraged for cardiovascular diagnostics in future research.

Xia et al.[20] explored smartphone-based sensors and analysis algorithms for point-of-care tests. While their research primarily focused on diagnostic applications beyond cardiovascular health, it underscored the potential of mobile health technologies and ML algorithms in enabling accessible and decentralized healthcare solutions, including cardiac diagnostics.

Gárate-Escamila et al. [21] created models of classification for cardiovascular disease forecasting based on choice of features and analysis of principal components.

González Bermúdez et al. [22] presented an integrated framework for providing multifunctional portable medical services. Although their research focused on the integration of diverse healthcare services rather than specific disease detection, it emphasized the potential of multimodal data fusion techniques in enhancing the capabilities of mobile health platforms for cardiovascular diagnostics.

Mohamed et al. [23] investigated anthropometry, or laboratory information, and genetic variations in an innovative approach to the early detection and assessment of nonalcoholic fatty liver disorder.

Mukto et al.[24] developed a real-time violence surveillance system based on DL algorithms. Although their study focused on crime prediction rather than healthcare, it underscored the potential of DL algorithms in processing large-scale data streams and making real-time predictions, which could be adapted for cardiac anomaly detection in streaming audio signals.

The integration of information in neurological marketing was examined by Quiles Pérez et al. [25], with a focus on heterogeneous analysis of biological signals.

Riaz et al.[26] proposed iPREDICT, an AI-enabled proactive pandemic prediction system using biosensing wearable devices.

All things considered, the reviewed literature highlights the increased interest in using ML and DL approaches to diagnose cardiac disease, emphasizing the possibility. The assessment of the literature offers insightful information about the present status of research on heart disease detection, highlighting significant advancements, research gaps, and opportunities for future investigations. The review elucidates the effectiveness of DL models, the versatility of ML techniques, and the integration of

wearable technologies in facilitating remote monitoring and early detection of cardiovascular abnormalities. It also underscores the importance of feature engineering, multimodal data fusion, and age-specific diagnostic models in enhancing the accuracy and robustness of cardiac diagnostic tools.

Table 1 lists some significant relevant work that has been done on aberrant heart sounds. The review of the literature points up important developments and promising areas in the fields of cardiovascular diagnostics and healthcare management. Heart sound segmentation

to machine learning-based image analysis and survey-based evaluations of AI applications are among the many approaches covered in the papers. Promising outcomes from these techniques have included better heart sound analysis performance, precise iron deficiency anemia diagnosis, and increased security for single-board devices. Nevertheless, a number of restrictions and unanswered questions remain even if these results provide insightful information about the possible uses of AI and ML methods. To determine the clinical effectiveness and dependability of many of the suggested techniques, especially in actual clinical settings, more validation is needed.

Table.1. Major Related Work

Author	Method	Methodology	Results Value	Key Findings	Limitations
Arjouni et al.[27]	Heart sound segmentation	Shannon Energy based noise- reduction	Improved performance of AI-based heart sound analysis	Proposed method is robust to noise in heart sound recordings	Limited validation on real-world clinical data
Asare et al.[28]	Machine learning	Image analysis for iron deficiency detection	Potential for non- invasive iron deficiency anaemia diagnosis	ML can accurately identify iron deficiency from conjunctiva images	Requires further validation in larger studies
Boroujeni et al.[29]	Survey	AI applications in wildfire management	A thorough analysis of AI's application in wildfire administration	AI has potential to improve pre-, active-, and post- wildfire management	More research needed to optimize AI for real-world wildfire scenarios
Sánchez et al.[30]	The models for automatic encoders and devices effectiveness.	Authenticating a single-board gadget.	Enhanced security for single-board devices	Proposed method offers strong user authentication	Limited testing on diverse hardware platforms
Schmid et al.[31]	Physics- informed neural networks	Acoustic property estimation	Improved accuracy in predicting acoustic properties	Physics-informed neural networks provide high-fidelity predictions	Requires significant computational resources
Jamil et al.[32]	Vision Transformer (ViT)	Valvular heart disease detection from PCG signals	Efficient and robust framework for VHD detection	ViT shows promise for accurate VHD detection using PCG	Lacks comparison with other deep learning architectures
Khozeimeh et al.[33]	Interactive Learning using Heterogeneous Classification methods	Identification of coronary artery illness	Improved clinical diagnosis accuracy	Ensemble-based active learning outperforms single classifiers	Needs validation on larger datasets with diverse patient populations
Mbungeet al.[34]	Deep and machine learning in the medical sector	Opportunities in sub-Saharan Africa	Possibility of enhancing healthcare delivery in an environment with limited resources	ML and DL have promising applications for medical treatment in Africa.	Information scarcity and infrastructure limitations pose challenges.
Maity et al.[35]	Transfer learning for heart valve disease classification	Phonocardiogram signal analysis	Improved classification of heart valve disease	Transfer learning demonstrates potential for accurate heart disease detection	Performance might vary depending on the chosen pre-trained model

In the future, these limitations and research gaps will need to be addressed in order to advance cardiovascular diagnostics and healthcare management. Future research efforts should focus on fine-tuning AI algorithms for practical scenarios, conducting comprehensive validation tests, and addressing infrastructure limitations in order to ensure the scalability and effectiveness of AI-enabled diagnostic tools. We can fully utilize AI and ML techniques to improve patient outcomes, improve healthcare delivery, and lessen healthcare disparities across various groups once these challenges are resolved.

ROLE OF MACHINE LEARNING AND DEEP LEARNING

The development of specific algorithms for biomedical applications, the availability of large healthcare datasets, and advances in computing methods have all helped to drive the expansion of machine learning and deep learning in medical diagnostics. Two DL techniques, Recurring neural networks and convolution neural networks, have shown cutting-edge results in a range of medical imaging tasks, such as the identification and segmentation of cardiovascular abnormalities.

Potential Applications in Cardiovascular Health

ML and DL algorithms can analyze diverse sources of data, comprising patient data, cardiac MRI images, echocardiograms, and electrocardiography (ECG) signals, in order to spot trends suggestive of cardiovascular problems. These algorithms can create precise predictive models that can help medical professionals diagnose and treat heart conditions by learning from big databases of clinical data and annotated medical pictures.

Sounds of heart

The noises made by the heart's contractions and the blood that circulation within it are commonly referred to as heart sounds, cardiac sounds, or heart sounds. Healthcare practitioners use these sounds as crucial clinical indications to evaluate the heart's health and function.

A stethoscope can detect the two primary heart sounds, which are commonly referred to as "lub-dub," as shown in figure 1.

First Cardiac Beat (S1): "Lub"

Often called "lub," the first heart sound is the lower-pitched and lengthier of the two. At the onset of ventricular systole (contraction), it happens When both tricuspid and mitral

atrioventricular valves are shut, initiating ventricular ejection.

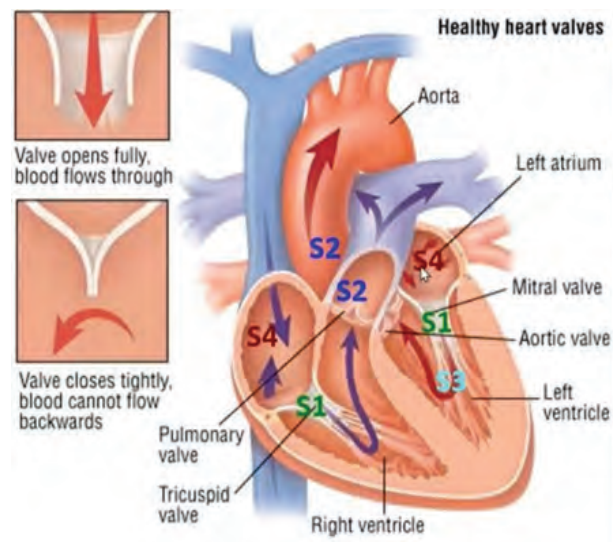


Fig. 1. Sounds of heart

Second Cardiac Beat (S2): "Dub"

Often referred to as "dub," the second heart sound is higher-pitched and shorter than the first. It happens when ventricular ejection ends and ventricular diastole (relaxation) begins when the semilunar valves (the aortic and pulmonary valves) close at the conclusion of ventricular systole.

The arterial and respiratory valves closed during cardiac relaxation, preventing blood from returning to the the ventricles. The noise is mostly caused by the shutting of the aorta and respiratory valves.

Third Cardiac Beat (S3)

Shortly after S2, in early diastole, the faint, low- frequency third heart sound—often shortened to S3— occurs. It is frequently audible in instances of increased ventricular volume or fluid overflow and is associated with rapid ventricular refilling within the early stages of dilation. S3 is frequently called a "ventricular gallop" and is common in pregnant women, young adults, and toddlers.

Fourth Cardiac Beat (S4)

Another faint sound that happens late in diastole, right before S1, is the fourth heart sound, which is frequently shortened to S4. It is frequently heard when there is decreased ventricular compliance or stiffness and is linked to atria contraction and resistance to ventricular filling.

S4 is also known as a “atrial gallop” and may indicate hypertension cardiovascular disease, a coronary artery disease, or a narrowing of the aorta. In clinical practice, the assessment of heart sounds using auscultation (listening with a stethoscope) is a fundamental component of cardiac examination. The quality, magnitude, time of day, and presence of other sounds can all provide important diagnostic information about the heart’s general function and health. Additionally, advancements in technology, such as echocardiography and Doppler ultrasound, allow for more detailed assessment of cardiac structure and function, complementing traditional auscultation techniques.

Table.2. Heart beat categorization

Category		Potential Cause
<i>Normal Sounds</i>		
First heart sound (S1)	Lub (low-pitched, tricuspid and mitral valve closure)	Normal heart function
Second heart sound (S2)	Dup (high pitched, pulmonary and aortic valve closure)	Normal heart function
Third heart sound (S3)	Dup (aortic, pulmonary, and high-pitched valve closure)	Rapid filling of ventricles, can be normal in young people
Fourth heart sound (S4)	optional, faint snapping sound	Atrial contraction, can be normal in older adults
<i>Abnormal Sounds</i>		
Murmurs	Swooshing, blowing or rasping sound	Turbulent blood flow due to valve stenosis (narrowing), regurgitation (leakage)
Gallop sounds	Additional rhythmic sounds resembling galloping horses	Ventricular dysfunction or abnormal filling of ventricles
Clicks	Sharp, high-pitched sounds	Valve prolapsed (incomplete closure)
Rubs	Scratching or grating sound	Pericardial inflammation (sac around the heart)

PROPOSED METHODOLOGY AND WORK PLAN

To reach research aims, use a multimodal strategy that combines audio signal processing techniques with ML and DL approaches. The research work plan includes dataset collection, feature extraction, machine learning classification, deep learning architectures, and multimodal integration.

CONCLUSIONS

This work attempts to improve the field of abnormal heart sound identification by utilizing deep learning and multimodal data integration. The primary objective of developing innovative approaches and procedures is to strengthen diagnostic capabilities and patient outcomes in the field of cardiovascular health.

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Empowering Communication in Indian Sign Language Recognition for Deaf and Dumb Individuals Using Deep Learning

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ABSTRACT

Modern technologies have developed new solutions that address the communication difficulties of individuals who have both hearing and speech disabilities. The research presents a modern communication solution through deep learning methods combined with Media pipe for the deaf and mute population of India. The developed system detects Indian Sign Language (ISL) gestures within live video footage before converting them into immediate text output. Through TTS technology the translated text becomes speech which enables non-signers to communicate interactively with the deaf and mute population. Our model employs advanced deep learning techniques of Convolutional Neural Networks (CNN) to recognize ISL gestures with high accuracy on diverse datasets. This breakthrough integrates advanced deep learning approaches with user-friendly interaction to break down communication barriers therefore enabling social inclusion and better life quality for Indians who are deaf and mute. The system demonstrates scalability and context-independent effectiveness because it adjusts to different ISL regional patterns. A machine-readable ISL dataset containing broad sign and gesture content features in this research publication. Through their combination, the CNN recognition system and Media pipe hand-tracking solution offer users effortless real-time ISL translation in a single system. The implementation of this solution brings multiple advantages which provide better accessibility educational possibilities and employment opportunities to individuals who experience hearing and speech difficulties. The research demonstrates how deep learning technologies can connect impaired and normal users effectively while promoting social comprehension. The system's portable design enables its integration with mobile and wearable technology which makes this tool useful for everyday use. Experimental findings show the effective potential of this technology when used in all educational social and professional environments to enhance deaf-hearing interactions.

KEYWORDS : *Convolutional Neural Network (CNN), Indian Sign Language (ISL), Text-to-Speech (TTS), Media pipe, Hand gesture recognition.*

INTRODUCTION

Hearing and speech disabilities create communication challenges for impaired individuals since modern tools often fail to perform smooth sign language translation effectively. In India, the primary language of communication between deaf and dumb people exists as Indian Sign Language (ISL). A lack of standardized accessible solutions for ISL recognition and translation prevents effective communication with non-signing people thus creating social and professional obstacles.

Filling this critical gap will support full accessibility and inclusivity in modern life because deep learning together with computer vision technologies have enhanced sign language recognition systems. This paper designs a modern I S L recognition system through the combination of Convolutional Neural Networks (CNNs) and the Media pipe framework which operates in real time. A CNN processes visual inputs effectively due to its ability to detect multiple complex visual patterns while Media pipe provides precise tracking of dynamic hand motions through its hand-tracking framework. The proposed system

achieves precise interpretation of ISL gestures through its integration of these technologies which results in text and speech outputs. The identified hand gestures pass through a classification process performed by CNNs. Corresponding ISL signs with high accuracy. This method improves recognition outputs and enables real-time processing which makes it useful for practical use in actual applications. This adaptable system can successfully process multiple gesture types and different regional signing methods which leads to better usage across various situations. The proposed solution demonstrates high potential within education and healthcare fields as well as social environments since it enables instant communication for hard-of-hearing people and general public group. The system enables effortless user interaction which helps users navigate through communication barriers to improve social connections between individuals. This investigation introduces a deep learning tool that enables ISL recognition thus connecting deaf and dumb communities across India through a flexible deployment model for mobile and wearable applications. The system which uses CNNs and Media pipe provides real-time signed language gesture transcription into speech and text as well as creates an accessible environment that benefits both inclusiveness and social equity. The gesture for thanking someone in American Sign Language (ASL) requires the forward movement of your dominant hand which follows a slightly downward path starting from your lips toward the receiver (Figure 1.0.1.b). Both hands are used in ISL (Figure 1.0.1.a) to create this sign which demonstrates unique differences between sign languages throughout their regions.

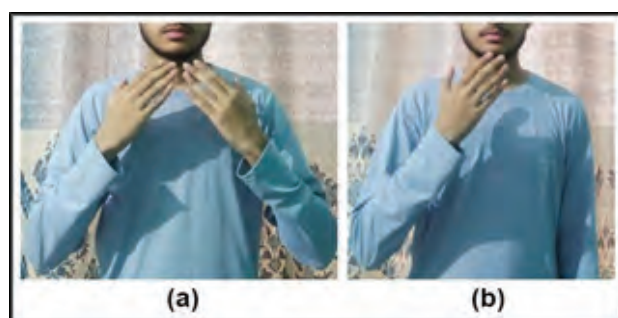


Fig. 1. Expressing ‘thank you’ with a) Indian & b) American Sign Language gestures.

Indian Sign Language (ISL) translation suffers from severe communication limitations since India has few accessible tools to convert ISL into text or speech for people with hearing and speech impairments. ISL recognition solutions currently available in the market fail to provide accurate

or adaptable and real-time processing features which obstacle inclusive and social integration. Standardized modern communication technologies are needed to bridge the ongoing communication gaps between deaf and dumb people and non-signers which affect their access to education work opportunities and social involvement. The resolution of this problem demands a strong real-time solution that implements advanced techniques of deep learning and computer vision to give precise gesture detection abilities. The research targets these obstacles through an ISL recognition system that combines CNNs with Media pipe to generate an all-encompassing solution for accessing facilities for deaf and dumb communities while promoting accessibility and inclusivity in Indian society.

LITERATURE REVIEW

Saqib et al. (2021) in their paper [1] introduce a method that uses CNNs with edit distance to recognize various complex gestures dynamically [1]. The authors describe how CNN performs dynamic gesture recognition through its ability to both track gesture time relationships and detect gesture spatial dimensions. The authors use edit distance metrics to analyze gesture sequence similarity that results in higher accuracy levels and reliable system performance. The system achieves better processing of complex gestures suitable for real-time operation when it integrates edit distance functions with CNN technology. This methodology shows its highest value in situations where gestures need instant changes such as sign language communication and human-robot interactions.

Mujahid et al. (2021) developed a real-time hand gesture recognition system through the implementation of YOLOv3 deep learning model in their paper [2]. Inside real-time applications YOLOv3 achieves fast accurate hand gesture detection because it possesses both detection and classification operations. This study describes YOLOv3's capability to address hand gesture spatial and temporal attributes that arise in moving environments. The training database needs to be diverse to enable the system to detect different gestures throughout its operational use. The research analyzes how system real-time capabilities affect training functions and inference operations to allow implementation in basic user interface setups and gesture control platforms.

A multi-level feature Long Short-Term Memory

(LSTM) network serves as the foundation for dynamic hand gesture recognition according to Do et al. (2020)

in their paper [3]. Traditional systems face challenges because they struggle to process diverse hand shapes together with sequence timing in a satisfactory manner as the authors describe. The multi-level feature LSTM network lets the system obtain both hand gesture spatial features and frame time dependencies. Better precision emerges from this method because it processes hand shapes together with sequences of hand gestures. This system demonstrates exceptional capability for detecting sophisticated movements that occur in sign language translation and human- computer interface applications.

The MultiD-CNN system received development from Elboushaki et al. according to their paper published in [4] the system utilizes RGB-D color and depth image sequences for gesture recognition operations. Multiple-dimensional features benefit from convolutional neural networks to enhance gesture recognition accuracy in three-dimensional processing according to the article. Hand gestures become discriminable thanks to the system which combines RGB and depth information since physical gestures having similar visual appearance can have different positioning in depth. This method demonstrates its greatest usefulness in identifying complex gestures within ever-changing environments such as virtual and augmented reality because it maintains accurate spatial perception as well as tracking abilities.

Kaczmarek et al. (2020) used their paper [5] to study how factory robots can be controlled by gestures together with voice commands in offline and online settings. The researchers combined these two input systems to prove how they increase both speed and versatility of robotic human interfaces. A predefined gesture set receives recognition through gesture recognition as a secondary control option together with voice commands. The document presents operational challenges alongside solutions which enable the unification of offline and online robot control methods through interfaces that do not need additional hardware components.

The research by Neto et al. (2019) discusses gesture-based human-robot interaction for industrial environments in their paper titled [6]. The paper explains how robot operators use gestures for command purposes and leads to improved industrial results with enhanced maintenance safety. Workers leverage machine learning to teach robots about hand gestures which function as command signals that replace both touch-based operations and complex control systems. The research study conducts a performance

evaluation of gesture recognition technology designed for material handling functions alongside assembly procedures and quality checks to determine its potential for human error reduction while improving manufacturing workflow conditions. The study identifies the necessity of developing logical user interface approaches which allow businesses to create better working spaces and protect workers from hazards.

The authors of paper [7] investigate modern automotive interface design with haptic gestures that operate in mid-air space according to Young et al. (2020). The authors created an interface system which drivers can control with hand movements without needing to touch the device thus delivering both better safety features and usability benefits. During user interactions this system employs haptic feedback as an interactive guide which delivers usability and responsive functionality to users. The implementation of gesture controls provides drivers with a safe method to operate navigation and entertainment and climate systems thereby keeping their eyes on the road. Various design obstacles affecting this technique include the need to confirm vehicle movement-based gesture precision as well as methods to reduce interface-related exhaustion during prolonged usage. Al-Hammadi et al. introduce in their publication [8] a deep learning method for sign language gesture recognition that innovates hand gesture representation techniques Deep learning methods function to improve both accuracy rates and speed for sign language gesture detection according to the authors. The authors create a new framework that detects the hand movement patterns and shapes since these elements are essential for distinguishing gestures that look similar. The authors use Convolutional Neural Networks (CNNs) to analyze hand gesture data thus achieving better recognition outputs. The hand- designed hand pose system aids the development of advanced sign language recognition solutions primarily intended for real-time applications in communication aids among individuals with hearing disabilities.

The Brazilian Sign Language (LIBRAS) database received development and validation under the research of Rezende et al. (2021) as described in [9]. The researchers established a large-scale LIBRAS gesture database as a foundation to make recognition systems operate more efficiently. Deep learning models require diverse annotated datasets for correct detection of sign language gestures to function effectively according to the paper. The authors conducted thorough testing which demonstrated their dataset can fulfill operational requirements by developing assistive

technologies for hearing-impaired people. The research enhances gesture recognition system development through its establishment of an essential database which helps experts who implement these systems.

The authors of paper [10] established a thorough gesture recognition system using Brazilian Sign Language (LIBRAS) database which underwent multiple validation tests according to Rezende et al. (2021). The authors built a multisource dataset for deep learning models that detect LIBRAS gestures to meet the requirement standards of sign language recognition research. The database requires gestures from different areas as this ensures real sign language application conditions are accurately represented according to the research team. The study verified the dataset through multiple machine learning tests which proved its success at enhancing gesture recognition accuracy in systems. The research output creates an imperative dataset that serves researchers and developers to advance assistive technology systems that benefit the deaf and hard-of-hearing population.

According to J. Semgulys et al. in their work [11], they establish methods to detect basketball referee signals from ongoing video streams. The research develops a specific gesture recognition system who's primary purpose is to analyze the activities of basketball referees during actual game scenarios. Through the combination of machine learning and computer vision methods, the authors develop a system that analyzes live video data to accurately recognize referee signals.[12][13] The paper demonstrates how specific gesture recognition plays a vital role in sports because the accurate understanding of official signals lets games run smoothly and supports fair competition.

PROPOSED SYSTEM

A real-time solution empowers ISL communication with deaf and mute individuals through deep learning and computer vision methods applied in the system architecture. A webcam system collects live video data which specifically follows user hand movements. The Media pipe framework processes the camera feed by performing real-time hand-tracking functions and landmark detection to obtain significant hand characteristics.

The features processed by a Convolutional Neural Network (CNN) accept inputs from a trained model that works with diverse ISL gestures. The trained CNN evaluates extracted patterns to determine the ISL gesture meaning with high precision in its classification. Users receive feedback

through a voice system that converts identified gestures together with on-screen presentation of the corresponding text output. Users benefit from accessible interaction since the dual feedback method functions across various contexts and preference settings. Real-time accurate ISL translation requires three essential elements because they ensure effective communication between deaf and hearing individuals. Communication between deaf and hearing people. The adaptable design enables system usability in the education sector, healthcare institutions, and social settings to enhance independent functioning through effective communication.

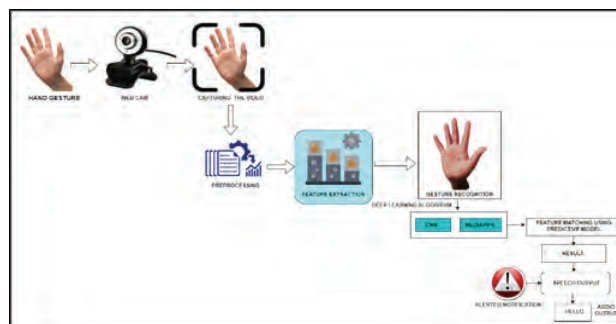


Fig. 2. Proposed System

METHODOLOGY

The real-time sign language detection system incorporates two process stages which involve Media Pipe hand tracking followed by CNN gesture classification to identify Indian Sign Language (ISL) gestures properly.

Hand Tracking Using Media Pipe

The real-time hand landmark detection function of Media Pipe provides instant discovery of 21 crucial points from the streaming video. The landmark data undergoes normalization and preprocessing steps to achieve better recognition when operated under different lighting conditions or hand orientation angles.

Gesture Classification Using CNN

The trained convolutional neural network applies classification to spatial hand features extracted from landmarks by processing input data from an ISL dataset. The model proceeds through feature extraction to identify distinguishing gesture patterns, retraining, and optimization to enhance accuracy and increase efficiency. Once trained, the CNN performs real-time mapping of the detected hand movements to the associated ISL symbols with high precision.

RESULTS AND DISCUSSION

The real-time sign language recognition system has been useful in assisting the deaf and mute with its media pipe along with CNN. The hand tracking of Media Pipe combined with pattern recognition of CNN enables gesture classification with outputs as text and speech. Basic gestures provide very accurate recognition, whereas complex gestures give rise to some discrepancies. Users consider it freestanding, easy to use, and applicable in classroom settings, clinical use, and everyday communication. The work presented here hopes to reinforce avenues for research by underscoring deep learning, coupled with computer vision, as an effective means of synergizing with the development of inclusive communication.



Fig. 3. Log in

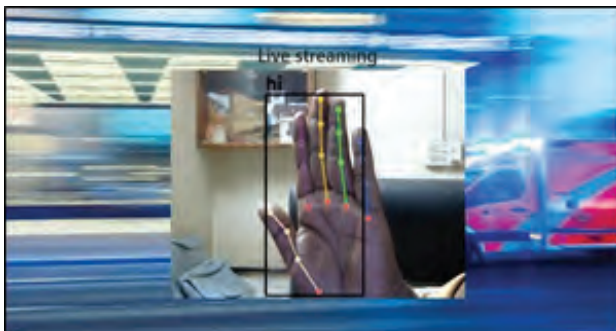


Fig. 4. Hand gesture detection

	precision	recall	f1-score	support
0	1.00	1.00	1.00	119
1	1.00	1.00	1.00	122
2	1.00	1.00	1.00	121
3	1.00	1.00	1.00	116
4	1.00	1.00	1.00	120
5	1.00	1.00	1.00	125
6	1.00	1.00	1.00	118
7	1.00	1.00	1.00	120
8	1.00	1.00	1.00	117
9	1.00	1.00	1.00	122
accuracy			1.00	1200
macro avg	1.00	1.00	1.00	1200
weighted avg	1.00	1.00	1.00	1200

Fig. 5. Classification Report

The classification report indicates that the CNN model used for Indian Sign Language recognition has achieved perfect performance across all classes. With precision, recall, and F1-score consistently at 1.00 for each class, it demonstrates high accuracy and reliability in correctly identifying the intended sign language gestures. This exceptional performance suggests that the model is well-suited for empowering communication for deaf and dumb individuals by accurately translating their hand gestures into the corresponding spoken language.



Fig. 6. Training loss and accuracy of the CNN model

The graph illustrates the training loss and accuracy of the CNN model used for Indian Sign Language recognition over multiple epochs. The model develops better pattern recognition abilities because the training loss continues to decrease. The validation loss never rises above a low point which indicates that the model does not over-fit while also demonstrating good ability to predict new data points. The model shows effective hand gesture classification ability through its training accuracy which quickly rises to achieve near-perfect performance. The model displays consistent success in Indian Sign Language interpretation because its validation accuracy stays elevated.

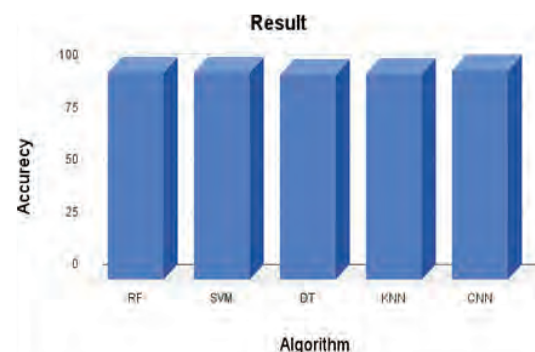


Fig. 7. Comparative result

The analysis presented in the bar chart demonstrates that Random Forest (RF) together with Support Vector Machine (SVM) and Decision Tree (DT) and K-Nearest Neighbors (KNN) achieved similar accuracy levels on the provided dataset. The outcome displays equal accuracies between these algorithms because the bar chart represents almost equivalent heights. These models demonstrate equivalent predictive accuracy performance on the specified dataset for this particular task.

CONCLUSIONS

This research develops a real-time Indian Sign Language recognition system to connect people who have hearing and speech impediments. The developed system utilizes CNNs to achieve exact gesture recognition while using MediaPipe technology to track hands with high efficiency. The integrated system translates ISL gestures precisely while converting them to text or spoken messages. Computer vision technology when fused with deep learning enables better access to social areas and educational settings thus increasing independence for deaf and mute groups leading to more inclusive communities within an equal society.

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GradeSense: Smart Grading for Descriptive Assessments

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ABSTRACT

The traditional process of evaluating subjective (descriptive) type exam papers for large numbers of students is labor-intensive and prone to inconsistencies due to human factors such as evaluator fatigue or mood. This manual evaluation method is also time-consuming, often leading to delays in result processing. In contrast, competitive and entrance exams with objective or multiple-choice questions benefit from automated, machine-based evaluation, which is faster, more accurate, and reduces human errors. However, there is currently no efficient system for automating the evaluation of descriptive answers. To address this challenge, we propose an innovative solution where student's handwritten answer sheets are scanned and uploaded into the system. Using advanced machine learning and natural language processing techniques, the system processes and evaluates the handwritten content, providing consistent and timely assessment. This automated evaluation system aims to streamline the grading process for educational institutions, enhancing efficiency, accuracy, and resource management.

KEYWORDS : *Subjective exam evaluation, Handwritten answer sheets, Machine learning, Natural language processing (NLP), Grading efficiency, Consistency, Educational technology, Resource management, Automated assessment system.*

INTRODUCTION

A Subjective Answer Evaluation System is a tool used to assess answers to open ended questions, commonly found in school tests, surveys, or feedback forms. [1] Unlike questions with clear right or wrong answers, subjective responses are more complex and need careful evaluation. These systems use guidelines or criteria to judge things like how relevant the answer is, its structure, creativity, and how well the content is presented. To do this, the system can use human evaluators, AI technology, or both. AI systems, especially those using Natural Language Processing (NLP), help analyze responses for grammar, clarity, and tone. A key part of these systems is reducing bias, as human judgment can sometimes be influenced by personal opinions. They also give feedback, offering suggestions for improvement or pointing out what was done well. These systems are used in various areas, from grading school essays to analyzing customer feedback.

The goal is to ensure fair, consistent, and thorough evaluation of different types of answers.[2] A Subjective Answer Evaluation System is designed to assess answers that don't have a straightforward right or wrong response, such as essays or opinion-based questions. These kinds of answers are often found in school exams, surveys, or feedback forms. Since they can be more complex and open to interpretation, the system uses a set of rules or criteria (called a rubric) to evaluate them. The rubric looks at things like how well the answer addresses the question, how clearly it's written, how creative or original it is, and how accurate the information provided is. To handle this kind of evaluation, the system might rely on people, computers, or both. For instance, AI tools that use Natural Language Processing (NLP) can help by checking things like grammar, the flow of ideas, and even the tone or emotion behind the answer. One important part of this system is making sure that any personal bias is minimized, so every answer is judged fairly. In addition

to giving a score or grade, these systems often provide feedback, helping the person understand what they did well and where they could improve. These evaluation systems are useful in many areas. In education, they help teacher's grade essays or written projects. In business, they help companies analyze feedback from customers to understand their experiences or opinions. The main goal of a subjective answer evaluation system is to make sure that each answer is evaluated in a fair, consistent, and detailed way. [1]

RELATED WORK

NLP-Driven Text Similarity Analysis

J. Wang and Y. Dong, Measurement of text similarity, International Journal of Engineering Research Technology (IJERT), 11th June 2020: This paper presents a method for measuring how similar two pieces of text are. The authors implemented a system that combines techniques from natural language processing (NLP) and mathematical algorithms to analyze the semantic (meaning) and syntactic (structure) similarity of text. The goal was to create a tool that can compare text in different contexts, such as evaluating documents, detecting plagiarism, or improving search engines. They used various statistical and linguistic techniques to ensure accurate measurement, focusing on both word-level and sentence-level comparisons.[1]

Deep Learning for Short Text Similarity

M. Han, X. Zhang, X. Yuan, J. Jiang, W. Yun, and C. Gao, A survey on the techniques, applications, and performance of short text semantic similarity, International Journal of Engineering Research Technology (IJERT), 9th April 2021: This survey paper reviews various methods and technologies used to calculate semantic similarity in short texts, such as tweets, messages, or search queries. The authors implemented comparisons of different algorithms and frameworks, evaluating their strengths and weaknesses in understanding the meaning of short texts. They highlighted how these techniques are applied in areas like Chabot's, question-answering systems, and recommendation engines. They also provided an in-depth analysis of performance metrics and challenges faced in handling ambiguous or context-dependent short texts. [2]

NLP for Key Points, Grammar & Semantic Matching

M. S. M. Patil and M. S. Patil, Evaluating student descriptive answers using natural language processing, International Journal of Engineering Research Technology (IJERT), 14th October 2014: This paper introduces a

system that uses natural language processing (NLP) to evaluate descriptive answers written by students. The system analyzes the text to understand its meaning and compares it against an ideal answer or set criteria to assign grades. It focuses on checking key points, grammar, and relevance rather than just word matching. The authors aimed to automate the grading process for long-answer questions, making it faster and more objective, while also ensuring fairness and consistency in scoring. [3]

Machine Learning-Based System

M. Han, X. Zhang, X. Yuan, J. Jiang, W. Yun, and C. Gao, Subjective answer evaluation using machine learning, International Journal of Engineering Research Technology (IJERT), 25th February 2021: This paper describes a machine learning-based system for evaluating subjective answers, such as essays or descriptive responses. The authors developed a model that learns patterns from a large dataset of manually graded answers. It considers factors like sentence structure, key concepts, and writing style. The model can predict scores for new answers based on its training, offering a scalable solution for educators. The system also identifies areas where students might improve their writing, making it useful for both grading and feedback. [4]

PROPOSED METHODOLOGY

Our proposed system automates the evaluation of handwritten descriptive answers by combining image processing, machine learning, and natural language processing techniques. First, students' answer sheets are scanned and converted into digital images. These scanned images undergo preprocessing steps such as noise removal, alignment correction, and text segmentation to ensure clarity and accuracy in data extraction. The system then identifies and extracts the handwritten text from the images using advanced handwriting recognition algorithms.[5]

Once the handwritten content is converted into text, the system uses natural language processing (NLP) to analyze the answers. It compares the extracted text with the expected answers provided by educators. Key evaluation criteria, such as the relevance of the content, grammar, structure, and the use of keywords, are considered during the grading process. Machine learning models are trained on a large dataset of sample answers to ensure fairness, accuracy, and consistency in scoring.[2]

The results of the evaluation are then compiled and presented to educators in an easy-to-review format.

Teachers can review the system's grading, provide feedback if necessary, and finalize the scores. This methodology not only saves time but also minimizes human errors and inconsistencies, making it a reliable and efficient solution for educational institutions handling large volumes of descriptive answer sheets.[1]

Content Relevance Score (CRS): The system evaluates the similarity between the student's answer and the expected answer using techniques like Cosine Similarity or Jaccard Similarity.

$$\text{Cosine Similarity} = \frac{\vec{A} \cdot \vec{B}}{\|\vec{A}\| \|\vec{B}\|}$$

The process begins by scanning students' handwritten answer sheets. High-quality scanners or even mobile phone cameras can be used to capture these sheets as clear digital images. To ensure the images are easy for the system to understand, techniques like removing noise, fixing any slanted text (skew correction), and converting the image to black and white are applied. This makes the text easier to read and process by the system.

Once the images are ready, Optical Character Recognition (OCR) software is used to extract the handwritten text. OCR is a tool that reads and converts handwriting into digital text. The extracted text is organized in a format that the system can process further. At this stage, the system also checks if the text is readable. If the handwriting is unclear or the OCR cannot recognize it properly, those sheets are flagged and sent back for manual review by a human evaluator. After extracting the text, the system uses Natural Language Processing (NLP) to break it down and understand it. First, it splits the text into smaller parts like words and sentences (tokenization). Then, it simplifies words to their root forms (lemmatization) and removes unnecessary words like "is" and "the" (stop word removal). This helps the system focus on the key parts of the answers and understand the meaning behind the text.

The system compares the student's answers to the correct or model answers provided by the teacher. It checks for important keywords, concepts, and whether the explanation matches the expected one. Advanced techniques, like calculating how similar the student's answer is to the correct one using mathematical methods, are applied. The system doesn't just look for exact matches but also evaluates how well the answer explains the concept.

Using machine learning models, the system assigns a score to each answer based on factors like relevance, grammar, and structure. It also generates a detailed report for each student, explaining how the score was calculated and providing helpful feedback. If the system encounters an unclear or complex answer, it flags it for a human to review, ensuring the grading is accurate and fair.

The final step is to provide an easy-to-use platform for teachers and students. Teachers can upload scanned answer sheets, track the grading progress, and download detailed reports. Students can log in to view their results and feedback. The system is built to handle large numbers of answer sheets at once, making it suitable for schools and colleges. Over time, the system can improve itself by learning from flagged cases or new data, ensuring it becomes even more accurate and efficient.

SYSTEM ARCHITECTURE

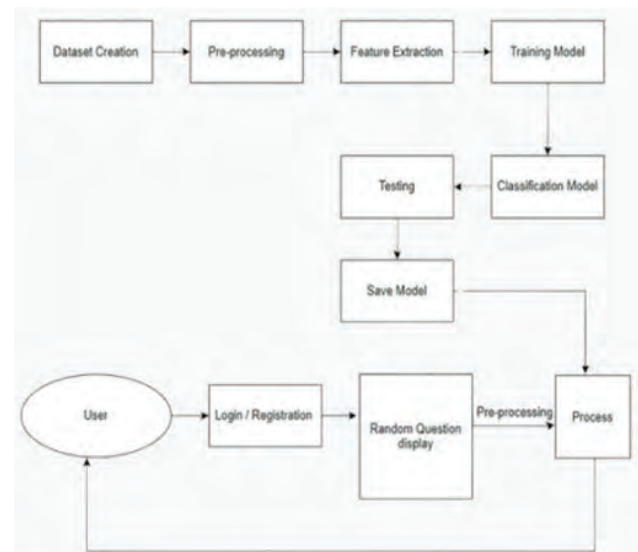


Fig. 1: Architecture Diagram

RESULTS AND DISCUSSION

The automated evaluation system was tested on a dataset of scanned handwritten answer sheets from students. The system successfully extracted text from the images with a high degree of accuracy, thanks to the use of advanced handwriting recognition techniques. Once the text was extracted, the answers were evaluated based on their relevance, grammar, and structure. The system provided scores that were consistent with those given by human evaluators in most cases, demonstrating its reliability in assessing descriptive answers.[1]

The results showed that the content relevance component, calculated using techniques like cosine similarity, was effective in identifying how closely a student's answer matched the expected response. Additionally, the grammar-checking algorithms detected errors accurately, providing a clear indicator of language quality in the answers. The structure evaluation ensured that answers followed a logical flow, considering elements like introductions and conclusions. Together, these components enabled a fair and balanced grading system.

This automated approach significantly reduced the time required for evaluation compared to traditional manual methods. It also minimized human errors and inconsistencies caused by factors such as fatigue or subjectivity. While the system performed well overall, some challenges remain, such as handling poor handwriting and complex, open-ended answers that require deep contextual understanding. Further refinements and training on larger datasets can enhance the system's performance and adaptability to diverse educational scenarios.

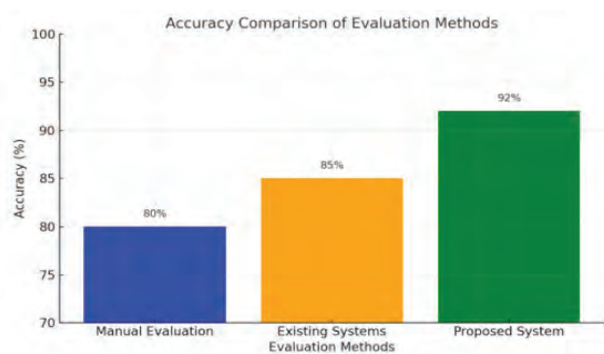


Fig. 2: Graph

The graph compares the accuracy of three different methods for evaluating descriptive exam answers: manual evaluation, existing automated systems, and the proposed system. Accuracy is the key metric used to measure the reliability of these methods in assessing answers. Manual evaluation has been the traditional approach but is prone to errors due to human factors. Existing automated systems improve on this by using technology to analyze answers but still face limitations. The proposed system, designed to overcome these challenges, demonstrates significantly higher accuracy.

Manual evaluation, represented by the first bar, shows an accuracy of around 80. This method relies entirely on human assessors, who are susceptible to inconsistencies caused by fatigue, mood, or subjective judgment. While

manual evaluation has been widely used, it often results in variations in scoring, especially when large volumes of answer sheets need to be graded. The graph highlights these limitations, indicating room for improvement in accuracy.

The second bar represents existing automated systems, which achieve an accuracy of approximately 85. These systems utilize basic handwriting recognition and text analysis techniques to evaluate answers. While they reduce human errors and save time, their performance is still limited by challenges such as poor handwriting recognition and difficulty in understanding the contextual relevance of answers. The graph shows that these systems offer a moderate improvement over manual evaluation but still fall short of optimal accuracy.

The third bar, representing the proposed system, demonstrates an accuracy of around 92, the highest among the three methods. This system uses advanced handwriting recognition, natural language processing (NLP), and machine learning algorithms to assess answers comprehensively. By addressing the shortcomings of both manual and existing automated systems, the proposed system provides consistent and reliable evaluation results. The graph clearly indicates that the proposed solution is a significant step forward in improving the accuracy of descriptive answer evaluation, making it a valuable tool for educational institutions.

PROBLEM DEFINITION

The manual system for evaluation of Subjective Answers for technical subjects involves a lot of time and effort of the evaluator. Subjective answers have various parameters upon which they can be evaluated such as the question specific content and writing style. Evaluating subjective answers is a critical task to perform. When human being evaluates anything, the quality of evaluation may vary along with the emotions of the person. This system can be used instead in order to reduce their burden. It will save a lot of effort and time on teacher's part. The human efforts applied in this repetitive task can be saved and spent more in other academic endeavors. The obvious human mistakes can be reduced to obtain an unbiased result. The system calculates the score and provides results fairly quickly.

FLOW CHART

This flowchart outlines the process of automating the evaluation of handwritten exam answers using technology, including machine learning and natural language

processing (NLP). It begins with scanning and uploading handwritten answer sheets to the system, ensuring that the input is digitized and ready for further processing.

The next step involves the system processing the handwritten content to check if the text is readable. If the content is readable, the evaluation is carried out automatically using machine learning algorithms and NLP techniques. If the content is not clear enough, it is flagged and sent for manual review by human evaluators to ensure accuracy.

Once the evaluation process is complete, the system generates a detailed assessment report. This report provides insights into the quality and completeness of the answers, helping educators or institutions streamline grading processes and provide fair feedback.

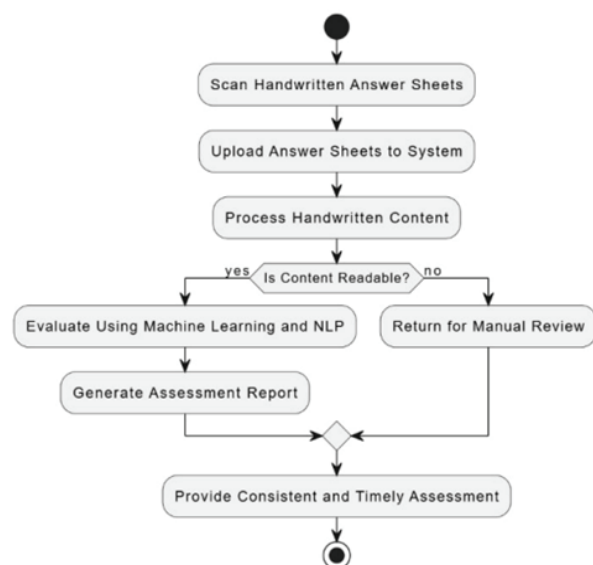


Fig. 3. Flowchart

Finally, the process ensures that the assessments are consistent and delivered on time, enhancing the efficiency and reliability of the evaluation process. This approach significantly reduces the workload for educators and speeds up result generation while maintaining accuracy.

ADVANTAGES

- **Time Efficiency:** Significantly reduces the time required for grading descriptive answers, enabling quicker result processing and academic decision-making.
- **Consistency and Fairness:** Eliminates inconsistencies caused by human evaluators' fatigue, mood, or bias,

ensuring fair and uniform evaluation for all students

- **Scalability:** Capable of handling large volumes of answer sheets efficiently, making it ideal for mass-scale assessments in schools, universities, and competitive exams.
- **Resource Optimization:** Reduces the dependency on human evaluators, freeing up resources for other educational activities and administrative tasks.

DISADVANTAGES

- **Complexity in Handwriting Recognition:** Variations in students' handwriting styles, poor handwriting quality, or unconventional writing may lead to errors in recognition and evaluation.
- **High Initial Setup Cost:** The development, deployment, and maintenance of such systems require significant financial investment and technological infrastructure.
- **Limited Contextual Understanding:** Automated systems may struggle to understand the nuanced or creative expressions in subjective answers, potentially leading to inaccurate evaluations.
- **Dependence on Technology:** A heavy reliance on technology may lead to disruptions in case of technical failures, system downtimes, or cyber-attacks.

CONCLUSION

The automated evaluation system for descriptive exam answers offers a reliable, efficient, and consistent solution to the challenges of manual grading. By leveraging handwriting recognition, natural language processing, and machine learning techniques, the system streamlines the assessment process, saving time and reducing human errors. It provides fair and accurate results, ensuring students are evaluated based on well-defined criteria like content relevance, grammar, and structure. While the system has demonstrated promising results, further improvements are needed to handle challenges like illegible handwriting and complex answers. Overall, this innovation has the potential to transform educational assessment, benefiting institutions and students alike.

FUTURE SCOPE

The automated evaluation system has great potential for further development and wider application. In the future, it can be enhanced to recognize a variety of handwriting styles, including messy or unconventional writing, and

support multiple languages for use in diverse regions. The system could also be adapted to handle more complex and open-ended answers by using advanced AI models that understand context better. Integration with existing learning platforms like Moodle or Blackboard would allow seamless adoption by schools and colleges. Additionally, it could provide instant feedback to students during practice exams, helping them improve. By creating mobile apps or cloud-based versions, the system could become more accessible to institutions with limited resources. These advancements would make the system more versatile, scalable, and valuable for educational institutions worldwide.

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Hastvani : Indian Sign Language to Text and Speech Translation

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ABSTRACT

A real-time Indian Sign Language (ISL) to text and speech translation program is the suggested remedy, which aims to close communication barriers between the deaf and hard-of-hearing community and non-ISL users. By translating ISL motions into precise, readable text and natural-sounding speech in several Indian languages, such as Hindi and Marathi, this program seeks to improve accessibility and inclusivity. The program will accurately recognize and interpret a large library of ISL signs and gestures by leveraging cutting-edge computer vision and machine learning technology. The technology will provide real-time translation by combining convolutional neural networks (CNNs) with natural language processing (NLP), guaranteeing that users receive text and speech outputs instantly and appropriately. The program will include an easy-to-use interface that makes communication simple and accessible to both hearing and ISL language users. Furthermore, based on user input and interactions, adaptive learning algorithms will continuously increase the accuracy of the system. This innovative solution is designed to significantly empower individuals who rely on ISL, fostering greater understanding and engagement in various aspects of daily life and promoting a more inclusive society.

KEYWORDS : Indian sign language, Real time translation, Text and speech conversion, Computer vision, Machine learning, Convolutional neural network, Natural language processing.

INTRODUCTION

A vital component of human contact is communication, which enables people to convey their thoughts, ideas, and feelings through written text, spoken language, body language, and facial expressions [1]. However, communication can be extremely difficult for those who have speech or hearing difficulties. In contrast to others, their primary means of communication with the outside world are hand gestures and sign language. Sign language is a sophisticated and graphically rich communication system that conveys meaning through body language, facial expressions, and hand gestures [2]. For the Deaf and hard-of-hearing groups, it is an essential communication tool that allows them to express their ideas, feelings, and experiences. Similar to spoken language, sign language is culturally and regionally specific, with each region creating

its own unique system of signs. For example, Indian Sign Language (ISL) is the primary means of communication for the Deaf community in India. ISL facilitates smooth communication between its users, but it is still highly unintelligible to non-users, which causes a communication gap between ISL users and the hearing population at large. This disparity has significant ramifications since it prevents people who depend on ISL from fully participating in society, accessing necessary services, education, and work opportunities. The difficulties posed by this communication gap emphasize how urgently technology solutions that can successfully close this gap are needed. The creation of a real-time Indian Sign Language (ISL) to text and speech translation tool is one such approach [3]. The goal of this cutting-edge program is to convert ISL motions into written text and spoken speech in Hindi, Marathi, and other Indian languages. By doing so, it has

the potential to empower individuals who rely on ISL, enabling them to communicate seamlessly with non-ISL users. The suggested application makes use of cutting-edge technology, including machine learning and gesture recognition, to reliably analyze ISL motions and translate them into a format that a larger audience can comprehend. In addition to encouraging inclusive communication, such a tool may lessen the obstacles that the Deaf and hard-of-hearing people encounter in a variety of spheres of life, including social contacts, work, healthcare, and education [3]. This system is a major step toward building a more egalitarian and inclusive society where everyone, regardless of ability, may participate fully and communicate effectively by serving as a bridge between ISL users and non- users.

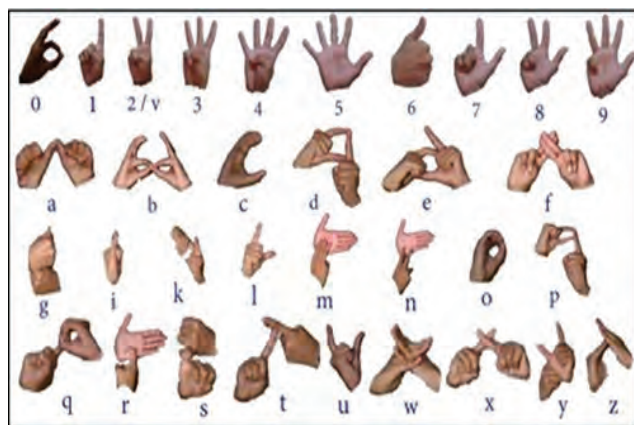


Fig. 1. Hand Poses in ISL [4]

EXISTING SYSTEM

1. The current approaches to translating Indian Sign Language (ISL) into speech and text mostly depend on human interpretation or a small number of technical solutions, which frequently lack scalability and accuracy in real time. The majority of current solutions are either static gesture-to-text apps that lack the dynamic capabilities required for smooth, daily communication or human interpreters that offer translation services in real-time. These methods have a number of draw- backs: 1. Manual Interpretation: Although they can translate ISL well, human interpreters are not always available, which could cause delays and restrict accessibility. Additionally, this method is very dependent on the interpreter's availability and proficiency, both of which can differ. 2. Simple Gesture detection Tools: While some current tools and applications make use of simple gesture detection technology, they frequently find it difficult to handle the complexity and

variety of ISL. These systems could produce inaccurate or insufficient translations due to their limited vocabulary and accuracy. 3.Lack of Real- Time Capabilities: A lot of the solutions available today lack real-time translation, which is essential for discussions to flow naturally. Rather, they may have a high delay or necessitate manual input, which would interfere with communication.

PROPOSED METHODOLOGY

People with hearing loss can communicate with each other via sign language. It uses body language and similar body actions hand gestures to convey messages. Interaction becomes a significant barrier and impacts communication because so few individuals are proficient in this language.

Data Collection

Any machine learning system, especially for gesture detection, starts with data collecting. A vast variety of pictures and videos that depict Indian Sign Language (ISL) gestures make up the dataset for this system. In order to connect each gesture in the dataset to its corresponding meaning—such as letters, words, or phrases—each gesture is carefully labeled. Because it enables the machine learning models to link certain hand gestures and postures to their semantic meanings, this tagging is essential for system training. Images and videos are taken in a variety of settings, such as with variable lighting, back- grounds, and viewpoints, to guarantee the dataset is strong and varied. In order to accommodate user variety, differences in skin tones, hand sizes, and movement rates are also included. This variety guarantees that the system can correctly identify gestures made by people with different physical attributes and in various settings. To further increase the dataset and the system's capacity for generalization, data augmentation techniques including flipping, rotation, and scaling are also used.

Gesture Recognition

The foundation of the ISL-to-text and speech translation technology is gesture recognition. A Convolutional Neural Network (CNN) model, which is very good at processing visual data, is used to do this task [5]. To recognize and decipher hand and body movements recorded by a video input, the CNN model is trained using the gathered ISL dataset [5]. Preprocessing the video frames to extract pertinent information is the first step in the recognition process. The system can concentrate on the shape and movement of the gesture by using techniques like edge detection to draw attention to the hand and body's contours.

Even in complicated situations, skin tone analysis aids in separating hand gestures from the background. In order to accurately identify dynamic gestures involving numerous positions, motion tracking is employed to examine the trajectory of hand movements across time. Following preprocessing, the CNN model examines the input frames and compares the identified gesture to the database of ISL motions that have been tagged. The algorithm ensures excellent recognition accuracy by using similarity scores to select the closest match. The system's performance is further enhanced by the ongoing improvement of the CNN model by training with a variety of datasets and cutting-edge methods like transfer learning.

Text and Speech Output

Following gesture recognition, the system employs Natural Language Processing (NLP) to translate the gesture into contextually relevant and grammatically correct text. A Text-to-Speech (TTS) engine then processes this text to produce speech that sounds natural. Users can select their chosen language for communication by using the system's support for output in Hindi, Marathi, and English, among other Indian languages. Better user engagement and wider accessibility are guaranteed by this multilingual capabilities.

APPLICATION

Education

Learning By helping Deaf and hard-of-hearing children communicate with teachers and peers who do not understand Indian Sign Language (ISL), the Indian Sign Language to Text and Speech Translation system has the potential to revolutionize education. By enabling the real-time translation of ISL gestures into speech and text, this technology can guarantee inclusive learning environments in the classroom [3]. It can also be included into online educational resources and remote learning platforms, ensuring that all students have fair access to digital learning materials.

Healthcare

Medical Care By facilitating successful communication between patients who use ISL and physicians, nurses, and other healthcare professionals, the system can help during medical consultations. Additionally, it can be extremely helpful in emergency situations where prompt and precise communication is essential. This eliminates the need for interpreters and guarantees that Deaf people receive timely and adequate medical care.

Public Services

Services for the Public By facilitating direct communication between Deaf people and personnel, this technology can improve accessibility in government buildings, banks, and other public sector facilities. Additionally, it can be utilized in public transit systems to translate announcements and information in real time, guaranteeing that everyone, regardless of hearing capacity, can access necessary services.

Media and Entertainment

Entertainment and Media By offering ISL translation for live TV shows, films, and internet streaming services, this technology can greatly increase accessibility in media and leisure. Additionally, it can be included into online meeting systems, guaranteeing that Deaf people can take part in interactive events and entertainment without any obstacles.

Accessibility in Technology

Technology Accessibility The accessibility features of smartphones, tablets, and other devices can be improved by integrating the ISL translation system [6]. This technology can also be used to improve the usability of smart home products and virtual assistants for Deaf people by allowing them to react to ISL gestures [6].

FUTURE SCOPE

In order to improve the efficacy and inclusivity of the sign language translation system, future research will concentrate on a number of important topics. By utilizing technologies like edge computing and multimodal learning, real-time translation enhancements seek to maximize machine learning algorithms for quick, accurate translations with the least amount of latency. Priority one is increasing language support, with plans to include more Indian languages and dialects. Regional variations of Indian Sign Language will also be addressed, and linguistic accuracy will be ensured by cooperation with native speakers and linguistic specialists. Customizable user interfaces will be created to improve accessibility. These will include features like font resizing and color contrast adjustments, as well as alternatives like complex settings for tech-savvy users and simplified layouts for low-literacy people. The system's relevance depends on community engagement, which involves Deaf populations through seminars, feedback sessions, and collaborations with advocacy groups to match the solution to user

needs. Finally, in addition to investigating cutting-edge technologies like AI-powered gesture recognition, research and development will keep concentrating on enhancing the precision and dependability of machine learning models by utilizing a variety of datasets and tackling environmental issues like dim lighting or background noise. By working together, these initiatives want to develop a strong, approachable, and inclusive framework for closing communication gaps.

CONCLUSION

An inventive way to improve communication for Deaf and hard-of-hearing people is the Indian Sign Language to Text and Speech Translation system. This technique is quite helpful, particularly for people who live in areas with limited access to resources and qualified interpreters. The research serves as a straightforward illustration of how CNN may be utilized to produce incredibly accurate solutions to computer vision problems. The project is able to address a portion of the Sign Language translation problem since sign languages are spoken more in context than as finger typing languages. The primary goal, which was to do away with the necessity for an interpreter, has been accomplished.

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Predicting Sugarcane Biomass and Nitrogen Using UAV LiDAR & Multispectral Imaging

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ABSTRACT

Precision agriculture increasingly uses advanced remote sensing technologies to optimize crop management and yield while minimizing environmental impacts. This study investigates Unmanned Aerial Vehicles (UAVs) equipped to leverage LiDAR and multispectral imaging technologies to forecast biomass and leaf nitrogen levels in sugarcane under different nitrogen fertilization conditions in Wet Tropics regions. Six UAV surveys, conducted at 42-day intervals, captured crop data, including measurements of crop height, density, and various vegetation indices. Predictive models were developed using both multispectral data individually, LiDAR data individually, and a combination of the two, in comparison to a normalized difference vegetation index benchmark. The multispectral-based model demonstrated the highest accuracy for predicting biomass early in the growing season, at 100–142 days after harvest (DAH), with an R^2 of 0.572, outperforming the LiDAR model ($R^2 = 0.522$) and NDVI benchmark ($R^2 = 0.342$). Toward the end of the growing season, the LiDAR-based model exhibited greater predictive accuracy. The fusion model showed limited benefits over individual models. Multispectral imagery also demonstrated moderate success in predicting leaf N content ($R^2 = 0.57$), highlighting its utility in early nitrogen deficiency detection. These findings underscore UAV based sensors' potential for fine-scale biomass and nitrogen prediction, enabling precise management in sugarcane cultivation. Future studies should explore integrating machine learning approaches and scaling these technologies across broader agricultural contexts.

KEYWORDS : Biomass prediction, LiDAR sensors, Multispectral sensors, Precision agriculture.

INTRODUCTION

Precision agriculture transforms traditional farming practices by leveraging advanced technologies to enhance crop management, optimize resource use, and minimize environmental impacts [1], [4]. Among these technologies, remote sensing with Unmanned Aerial Vehicles (UAVs) has gained prominence for its ability to generate high resolution, near-real-time data on diverse crop attributes [1], [5]. UAVs equipped with LiDAR (Light Detection and Ranging) and multispectral sensors are particularly valuable tools in precision agriculture, offering valuable insights into crop attributes including biomass and nutrient levels, which are critical for effective decision-making [3], [4], [6]. Accurate forecasting of

biomass and leaf nitrogen levels is crucial in sugarcane cultivation to optimize fertilizer application, improving crop yield, and minimizing environmental degradation [6]. Traditional methods of monitoring these parameters often involve labour-intensive, time-consuming field sampling and destructive testing, which are not feasible on a large scale [5]. UAV-based remote sensing offers a promising alternative, allowing rapid, non-invasive, and fine-scale monitoring of crop growth and health across large areas [1], [4]. Previous research has examined the use of UAV-mounted LiDAR and multispectral sensors to estimate crop biomass and leaf nitrogen content, providing data that can enhance fertilizer management and support sustainable production [2], [6]. However, the comparative

effectiveness of these sensors and their combined use for predictive modelling in sugarcane remains underexplored. This system examines the efficacy of UAV-mounted LiDAR and multispectral sensors in forecasting sugarcane biomass and leaf nitrogen levels under different nitrogen fertilization treatments and assess the benefits of data fusion for improving prediction accuracy [6].

LITERATURE REVIEW

The first paper, “Fine-scale prediction of biomass and leaf nitrogen content in sugarcane using UAV LiDAR and multispectral imaging”, examines the integration of UAV mounted LiDAR and multispectral sensors to improve the forecasting of sugarcane biomass. This research is significant in precision agriculture, aiming to optimize yield predictions and nutrient management. The study investigates whether the integration of LiDAR and multispectral data collected from UAVs can enhance the predictive accuracy of sugarcane biomass estimations and leaf nitrogen (N) content. It seeks to determine the most effective way to predict these metrics early in the growing season to support better management decisions, especially regarding nitrogen fertilizer applications. The research was conducted on two sugarcane field sites in the Wet Tropics of Australia. The sugarcane variety monitored was Q208A, planted on different soil types to introduce variability in biomass and nitrogen content. Six UAV surveys were conducted at approximately 42-day intervals to capture data from early growth to pre-harvest stages. The study’s findings can be applied to early-season biomass prediction, which can help farmers make timely decisions regarding fertilizer application and harvest planning. Future research could explore machine learning models (e.g., neural networks) to enhance predictive capabilities using fused LiDAR and multispectral data. There is potential to explore real-time UAV data processing to provide immediate insights for field management.

The second study, “Leveraging Machine Learning for Predicting Leaf Nitrogen Content in Sugarcane Using UAV Data,” explores the utilization of UAV-based multispectral imaging integrated with machine learning algorithms to accurately estimate leaf nitrogen content in sugarcane. This research harnesses various vegetation indices derived from multispectral images, such as NDVI, DVI, and RVI, which are robust indicators of nitrogen levels in crops. The investigation evaluated the predictive performance of multiple ML models, including Partial Least Squares Regression, Support Vector Regression,

and Random Forest. The results indicated that PLSR and SVR models were the most effective when applied to individual sugarcane varieties, achieving a high coefficient of determination and low Root Mean Square Error. Conversely, when data from multiple varieties were combined, the RF model exhibited superior performance with an R^2 of 0.66. The study underscores the potential of using UAV-based multispectral data integrated with machine learning for non-destructive, real-time monitoring of crop health, emphasizing the significance of developing variety-specific prediction models to optimize nutrient management in sugarcane farming. This research highlights the advantages of using UAV technology and machine learning techniques to accurately estimate leaf nitrogen content, which can inform precision agriculture practices and improve overall crop management strategies in sugarcane production.

The third paper, “Real-Time Biomass Estimation in Dense Crops Using UAV-based SLAM LiDAR Systems” (2024), explores the integration of UAV-mounted LiDAR sensors with Simultaneous Localization and Mapping (SLAM) technology for precise, real-time biomass estimation in dense crop environments. This study addresses the challenges of measuring above-ground biomass (AGB) in densely planted crops like sugarcane, where traditional remote sensing techniques often struggle due to canopy occlusion. The research focuses on using UAV-based SLAM LiDAR systems to generate high-resolution 3D point clouds, allowing for detailed measurements of canopy structure. The SLAM technology enables accurate data collection even in environments with complex, overlapping canopies, enhancing biomass estimation by penetrating dense foliage. The study found that combining LiDAR derived height metrics with structural volume indices improved the accuracy of biomass predictions compared to conventional multispectral imaging alone. The system demonstrated high predictive power with correlation coefficients exceeding 0.85 for biomass estimation across multiple field trials, establishing it as a valuable instrument for real-time maximization. agricultural surveillance and yield.

In conclusion, these recent research efforts collectively highlight the transformative impact of advanced UAV technologies, multispectral imaging, and machine learning in precision agriculture. The paper on the fusion of UAV LiDAR and multispectral imaging demonstrates that combining structural and spectral data significantly enhances early-season biomass prediction, enabling

more efficient fertilizer management in sugarcane crops. Meanwhile, the machine learning approach for predicting leaf nitrogen content shows how UAV-derived vegetation indices can be integrated with ML models to provide accurate, non-invasive nutrient assessments, aiding sustainable crop management.

METHODOLOGY

Problem Definition

Define the problem to accurately estimate biomass and leaf nitrogen levels in sugarcane fields through remote sensing techniques. This includes identifying the challenges of traditional methods in capturing fine-scale variations and the need for automated, high-resolution predictions to support precision agriculture.

Data Collection and Analysis

- **Gather Data:** Collect high-resolution data from UAVs equipped with LiDAR and multispectral sensors over sugarcane fields to capture structural and spectral information.
- **Implement Mechanisms:** Set up UAVs with predefined flight paths and sensor configurations to capture comprehensive data across different sections of the field, ensuring coverage and consistency.
- **Data Preprocessing:** Clean and preprocess the collected data by aligning LiDAR and multispectral datasets, removing noise, handling missing values, and normalizing formats to ensure quality and compatibility for analysis.

Feature Engineering

- **Extract canopy height** from LiDAR data as an indicator of biomass.
- **Calculate NDVI and NDRE** from multispectral data to estimate nitrogen levels.
- **Include field zones** to capture regional variations.
- **Use PCA** to simplify data, focusing on the most predictive features.

Model Development

- **Select Algorithms:** Utilize appropriate machine learning algorithms, including Random Forest and Extreme Gradient Boosting, to forecast biomass and leaf nitrogen levels effectively, as these models handle complex data relationships and can interpret feature importance effectively.

- **Train the Models:** Divide the pre-processed dataset into training and evaluation subsets. Train both the Random Forest and XGBoost models by tuning hyperparameters through cross-validation on the training set, with the objective of maximizing predictive accuracy and minimizing error.
- **Feature Importance Evaluation:** Evaluate the models to determine the importance of each feature in predicting biomass and nitrogen levels. This helps in identifying which spectral and structural attributes most influence the predictions, guiding further model refinement and interpretability.

Model Evaluation

- **Performance Metrics:** Evaluate model performance using metrics like Mean Absolute Error, Root Mean Square Error, and Coefficient of Determination to assess the accuracy and consistency of biomass and nitrogen level forecasts.
- **Comparison of Models:** Evaluate the predictive performance of the Random Forest and XGBoost models in order to ascertain which provides better predictive accuracy and generalization for the given dataset.

Integration of ML Algorithms

Random Forest: A powerful ensemble learning method that combines multiple decision trees to improve prediction accuracy. It works well with large datasets and handles non-linear relationships, making it ideal for modeling complex interactions between features like canopy height and spectral indices.

Documentation

Maintain comprehensive documentation throughout the system, detailing all methodologies, model configurations, performance metrics, and findings. This includes recording data collection protocols, feature engineering processes, and model evaluation results. Documentation should also cover the integration of unmanned aerial vehicle data and machine learning models, promoting transparency and replicability in forecasting biomass and nitrogen levels.

RESULTS

Analysis of biomass prediction models revealed significant temporal and sensor-dependent performance variations. During early growth stages, multispectral models exhibited superior predictive capability,

attaining peak accuracy at 142 days after harvest (DAH; $R^2=0.57$), likely attributable to their enhanced sensitivity to spectral reflectance patterns in developing vegetation. In contrast, LiDAR-derived predictions demonstrated progressive improvement as the season advanced, surpassing multispectral performance during late-season stages characterized by dense canopy closure. Notably, the fused model integrating LiDAR and multispectral predictors exhibited no statistically significant enhancement ($p>0.05$) over individual sensor-based models at any growth phase. The normalized difference vegetation index (NDVI), employed as a benchmark, underperformed relative to both multispectral and LiDAR approaches, particularly under dense vegetation conditions ($R^2=0.34$), highlighting its limitations in advanced phenological stages. Temporal analysis identified an optimal prediction window at 100–142 DAH, coinciding with peak biomass accumulation and maximal differentiation of nitrogen (N) fertilization effects. For leaf nitrogen content estimation, multispectral data achieved moderate predictive accuracy ($R^2=0.57$), successfully discriminating plots with deficient N application (e.g., 0 kg N/ha). Sensor-specific evaluations underscored divergent operational advantages: multispectral systems proved cost-effective for early-season biomass estimation and N diagnostics, whereas LiDAR demonstrated enhanced efficacy in late-season biomass modeling, robustness under low-light conditions, and operational independence from GNSS infrastructure. Subsequent validation protocols included comparative model assessments across phenological stages (early growth, maturation, flowering) using F-tests, temporal consistency evaluations across six UAV surveys (42-day intervals), and spatial validation of fine-scale (2 m $\times$ 2 m) predictions against in situ biomass measurements. Results confirmed UAV-derived models as viable for high-resolution biomass mapping, while deployment scenarios emphasized multispectral sensors for early-stage, large-scale applications and LiDAR for precision monitoring in dense canopies or harvest-proximate intervals. These findings underscore the criticality of phenology-aligned sensor selection to optimize prediction accuracy in agricultural remote sensing.

CONCLUSION

In conclusion, this system aims to leverage UAV technology and machine learning techniques to accurately predict biomass and nitrogen content in sugarcane fields, ultimately contributing to more efficient agricultural practices. Through the integration of LiDAR and multispectral imaging with advanced data processing and machine learning models, the system will provide valuable insights for precision farming. By addressing the challenges of data quality, model accuracy, and system scalability, this system has the potential to improve crop management and resource optimization. Future enhancements, such as expanding to other crops or incorporating more sensor types, could further elevate the system's capabilities, making it a vital tool in the evolving field of agricultural technology.

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AI-Powered Railway Grievance Resolution Portal

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ABSTRACT

The Indian Railways, a vital component of the nation's infrastructure, is a daily lifeline for millions of people. Millions travel daily to earn a living, meet their family, and tour a new place. However, the passengers must face numerous hassles handled by the concerned authority for several reasons. RailMADAD is a railway grievance management portal available on web and mobile platforms. Currently, passengers use RailMADAD to report any issue related to cleaning, catering, or having a poor experience with nuisances. The Railways on the backend try to solve their queries, but the real-world challenges limit them. This project will help resolve this issue by using artificial intelligence. Different machine learning models are used for categorizing and prioritizing complaints. Additionally, the passenger gets great user Experience to passengers with the help of chatbot assistance. This enhanced system can anticipate issues and maintenance by scrutinizing registered grievances and reducing future complaints. The evaluation criteria include accuracy of complaint categorisation, complaint resolution speed, great user experience and scalability. This AI-driven technique has the power to enhance the competence and productivity of the RailMADAD platform, enhancing the passenger experience.

KEYWORDS : RailMADAD, Artificial intelligence, Optical character recognition, Chatbots, Complaint management, Passenger experience.

INTRODUCTION

Indian Railways, a leading railway network worldwide that carries millions of people and goods daily is an integral part of India's economy and the most preferred transport medium by the people of India. Despite having such a vast number of passengers regularly, the passengers have to face many problems regarding cleanliness, safety, theft, food, etc. To deal with such issues, Indian Railways introduced an online grievance resolution portal called "RailMADAD." RailMADAD is an online web application that lets the passenger register their complaint, which is then resolved by railway personnel. Although the system is web-based, it still consists of some human components, as the whole resolution process is manual-driven. The existing system has no automated mechanism to categorize and prioritize the complaints. Instead, it relies on humans for complaint categorization and prioritization.

The complaints are manually categorized and then assigned to the staff concerned with the complaint. Such a process increases the response time, and as a result, the system becomes inefficient in solving the problems. The existing system needs a solution that uses modern tools and technologies to overcome these issues.

In this paper, we are going to examine how modern technologies like AI (artificial intelligence) and ML (machine learning) could be used to improve existing systems. With the help of AI, the current system will automatically categorize the complaints and prioritize them on the basis of seriousness of the problem. Along with these, the system will consist of various features such as automated assignment of complaints to the staff concerned with the complaint, complaint tracking, feedback collection, and analysis system. The system will generate useful insights and visualizations based on

outcomes of the feedback analysis that can be used for future reference. The main goal of the current system is to improve the efficiency and response time of the resolution process.

I. LITERATURE SURVEY

The research on the domain of machine learning-based approach to help businesses manage customer interactions on social media platforms like Twitter by prioritizing urgent tweets implies that the problem is how to deal with the massive amount of data posted daily when all the messages need to be answered in time, and sentiment analysis is used to analyze the text and categorize it into positive, negative, or neutral sentiments. The proposed system uses Random Forest, Support Vector Machine, Logistic Regression, and Naïve Bayes algorithms. It preprocesses unstructured data and carries out feature extraction and multiple model assessment to select the best classifier. Using pipeline-based vectorization, the system can efficiently process new tweets, which explains how machine learning can be helpful in the time-critical resolution of customer issues [1].

This new research discusses the significant improvement in Natural Language Processing (NLP) that has enabled the machine to better understand and interact with practical human language details. It discusses trends in technical language models and deep learning. The research also examines the growing curve of NLP across various industries and its role in human-computer interaction [2]. On the basis of analysis of the current tendencies and future directions, it presents a diversified review of the state-of-the-art in NLP and its transformative potential in improving the communication between humans and machines.

This research presents the use of CURD technology to improve disaster management. The system for addressing the above-mentioned challenges of data spam and its urgency is therefore presented. It uses a deep learning pipeline (CURDdl) of transformer models, convolution layers, and custom attention mechanisms, in addition to a multi-level annotation process of event type, relevance, and urgency. Experimental results show that F1 scores and accuracy of over 88% and AUC of more than 94% are achieved, which are better than the related works [3]. The annotated dataset and code of CURD are available to the public and can be helpful in helping make decisions and allocating resources in emergency situations.

New research addresses the highly critical issue of railroad safety by analyzing social media data that interprets public and stakeholder engagement. Using a dataset of 93,239 tweets over the last five years, this study will rely on user and retweet analysis, BERTopic modeling, sentiment and emotion analysis, and hashtag/mention analysis to analyze perceptions and behaviors with regard to railroad safety. Among the salient topics are culture of safety, teaching children railroad safety, headsets or earbuds use, trespassing, and emergency alerts [4]. The findings point out the inconsistent attempts between stakeholders in using Twitter for safety messaging, indicating potential barriers linked to organizational policies and strategies. The paper highlights the need for leadership support and collaboration between stakeholders to enhance social media's role in improving railroad safety awareness and public engagement.

The research is aimed at conducting sentiment analysis in the growing airline sector by analyzing consumer feedback from airline reviews. Sentiment analysis, a technique to categorize texts as positive or negative using machine learning, is employed to examine the sentiment of texts. The research compares the results of various machine learning algorithms, featuring Naive Bayes, Support Vector Machine, and Decision Tree, and chooses the best one. Additionally, BERT by Google, which has been pre-trained on masked language modeling and sentence prediction, is also assessed against these models [5]. The outcomes show that BERT overshadows other techniques in accuracy, precision, recall, and F1-score in contrast with the Random Forest model, which means that BERT is very efficient for the sentiment classification of airline reviews.

The research paper about automation in grievance registration authored by G Sidharth, Abijeeth Vasra, S Sridevi, C Deisy, M K A Ahamed Khan studies the application of Machine Learning frameworks like MobileNet V2 which is specially designed to include Deep learning (DL) algorithm, mainly Image classification [6]. Such a system incorporates the use of AI for process automation. The prime focus of the researchers was to develop a mobile application for an automated grievance registration system. The system uses algorithms like MobileNet V2, Depthwise convolution, and TensorFlow Lite, achieving higher accuracy. The convolution-based models are generally executed between 10% and 50% more quickly.

A survey on the challenge of managing the overwhelming

volume of user interactions on Twitter faced by Indian Railways says that, social media mediums like Twitter allow users to share their opinions, suggestions, and complaints, often requiring timely organizational responses [7]. Due to raw data, it becomes complex to resolve all queries. The implemented idea separates tweets based on their nature and urgency, which leads to efficient grievance management. This system helps the railway administration respond effectively to user feedback and evaluate service quality, improving overall customer satisfaction.

The research on a framework leveraging Natural Language Processing (NLP) and sentiment analysis to classify tweets related to public feedback for the Railway Ministry states that, online media, most probably Twitter, leads to significant media for data distribution and citizen involvement, where people share their views on politics, governance, sports, and other topics [8]. The analysis done on this data provides insights for enhancing public services. However, the unstructured nature and high velocity of complaint tweets pose a challenge to efficient processing. The system distributes tweets into multiple categories, leading to accuracy.

The survey on AI domain presents a summary of the use of AI in railway transport. It examines its impact on planning and control, maintenance and management, safety and security, and its impact on various aspects. Subsectors include autonomous driving, financial management, transport policy, and human mobility [9]. The review, which includes 139 papers published between 2010 and 2020, shows that most research efforts focus on AI in railway planning and management, while areas such as transport policy and financial management are under-researched.

Another promising research presents a well-ordered review of text-based railway transport research, focusing on the increasing role of natural language processing and text mining for the extraction of knowledge from large stores of text data. In a review of 107 publications from the last decade, it is found that there are many varied sources of railway-related text data, and their corresponding application use cases are examined. The review brings state-of-the-art machine learning and NLP techniques to the forefront and uncovers research directions critical for advancing the industry. The four identified directions are multilingual NLP, digital maintenance, external data integration, and developing railway-centric solution pipelines, duly informed with insights by Siemens

Mobility on current challenges and opportunities [10].

A work by Mayank Kejriwal and Peilin Zhou focuses on discovering impulsivity in short message problems by implementing a transfer learning approach. This research focuses on the use of minimally invasive techniques and transfer learning [11]. The data was collected from various social media platforms, including Twitter. The main objective of this application is to provide accurate and fast situational information so that things can be managed effectively and facilitate rapid response during humanitarian disasters. The researchers compared their work with different algorithms and found that their method was more effective than others, with an accuracy of 61.18%.

A research paper by Shovan Chowdhury and Marco P in the group of research papers using supervised machine learning methods. Schoen investigated ways to automatically generate research papers using ML algorithms like Support Vector Machine, Naive Bayes, K-NN, and decision trees [12]. This survey tracks the performance of different algorithms in a group based on evaluation measures such as accuracy, recall, F1 score, precision, and others. It is seen that SVM performs best among all the algorithms used, with an accuracy of 88.8%.

Another study shows the use of data mining and clustering methods in analyzing complaints from the SMS Complaints Service of the Ambon Municipal Government [13]. The research categorized the complaints into six areas: public services, infrastructure, governance, health, education, and society. This paper uses the Bayesian polynomial fuzzy method and focuses on evaluating the effects of both basic and non-basic methods on classification accuracy. The results show that the correction improves the accuracy to 91.38%, compared to 90.73% without reduction.

The research on a new technology like Smart Complaint Management System (SCMS) that intends to eliminate customer disappointment caused by service delays and a lack of complaint mechanisms resulted in the development of an application that includes mobile applications, chatbots, and web applications to reduce the grievance management process [14]. SCMS can automatically categorize complaints, route them to the appropriate department, and identify similar complaints to avoid duplication. Test outcomes show that the system efficiently reduces the time and process of filing complaints, expands existing complaint channels, facilitates reporting and tracking progress.

The research on a framework developed by the Pune Municipal Corporation (PMC) to improve citizen complaint registration in the city. Registering complaints over the phone is time-consuming and requires citizens to wait for a response from the service provider. The proposed system allows citizens to register complaints in natural languages and receive quick responses. The main problem addressed by the framework is the use of short, noisy, and ambiguous texts, which disrupt traditional textual methods. To overcome this problem, the system uses WordNet to extract semantic information and machine learning algorithms to understand the input [15]. Also, psychological evaluation is used to prioritize grievances based on urgency.

METHODOLOGY

Functional Specification

The modules required to complete the functionalities of the application are under the system's functional specifications. These requirements determine whether the functional objective of the system has been met or not. To fulfill the operational and functional objective of the system, functional requirements must be completed within the time constraints. The following are the functional specifications of the system:

1. To collect enough data to train the AI model to be able to perform and fulfill categorization functionality of the system.
2. Implementing the AI model for urgency detection by training the model against the adequate dataset.
3. To retain the precision of the AI model by training and testing against the reasonable dataset collected.
4. Integrating the AI Chatbot that will help to achieve user-friendliness by assisting the passenger for system usage and complaint submission.
5. To extract relevant data from the complaint description provided by the passenger to obtain the accurate results by utilizing the AI models.
6. To automatically route the complaints to the respective department using smart routing to eliminate manual work.
7. To add live complaint tracking for the passengers to track their complaints and to achieve transparency.

8. To collect passengers feedback to perform sentiment analysis on it to analyze the area for improvement and system maintenance in future.

Non-Functional Specification

The non-functional specification refers to the actual working of the system that determines whether the users and stakeholders are satisfied by the system or not. These specifications validate whether the system will be able to acclimate in the real environment. Non-functional specifications check whether the developed system is operationally feasible to adapt the stress condition to fulfil user requirement.

1. All the users must be able to access the system easily by registering into the system using the mobile number or email ID.
2. The user interface of the system must be user-friendly for all age groups, ranging from teenagers to senior citizens.
3. The chatbot must give an accurate and feasible response to users' queries.
4. The categorizations of the grievances made by the AI model must be accurate in assigning them to the appropriate department.
5. Assignment of priority to the grievances must be done based on the severity of the situation.
6. The system must with stand with heavy number of complaints and must be efficient and accurate even in stress conditions.
7. The staff must update the status of the complaint accurately whether the complaints are resolved or not.

C. Modules of AI-powered Railway Grievance Resolution Portal

The AI-powered Railway Grievance Resolution Portal consists of three modules in the system. The specifications of these modules are as follows:

Passenger Module

In the passenger module, the passenger will first enter the login credentials, after which the passenger will be directed to the grievance registering page, where the AI Chatbot will provide assistance for system usage. The passenger will enter the PNR number and the complaint description, which will be submitted afterward. The passengers can

also track their grievances to check the status and time to resolve their complaints. After complaint resolution, feedback will be collected from the user so that sentiment analysis can be performed.

Staff Module

The grievances submitted by the passengers will be categorized and prioritized based on the category and severity of the complaints, respectively. The categorized and prioritized complaints will be directed to respective departments, after which these complaints will be allotted to the respective staff automatically. On the staff dashboard, the staff can see the complaints that are allotted to them. Here, after clicking on the particular complaint, the staff can see the description, location, time, severity, and status of the grievance. The staff will be able to update the complaint status whether the complaint is resolved or not.

Admin Module

The admin module will be handled by the admin of the system, where he will first login into the system after which he will be directed to dashboard where the admin can handle all the other modules and the database of the system.

Workflow of the System

Fig 1 shows the workflow of the AI-powered Railway Grievance Resolution Portal, which highlights that the complainant will first submit the complaint with the assistance of an AI-Chatbot, after which he/she will get the acknowledgment of the complaint submission by getting the RRN number of the complaint. After this, the complaint categorization and prioritization will be done using the AI model. The categorized and prioritized complaints will be automatically routed to the respective department that will be assigned to the respective staff, and this will be done using smart routing. After the complaint is allocated to the respective staff, the staff will continue to update the complaint status, which will be tracked by the passenger. The staff will also update the status of the complaint when it is resolved. If the complaint is resolved, then the feedback will be collected from the passenger, and if the complaint is not resolved, then the staff will be notified to resolve unresolved complaints. The feedback that will be collected from the passenger will be analyzed to perform sentiment analysis on it, which will be used in analyzing future improvement areas.

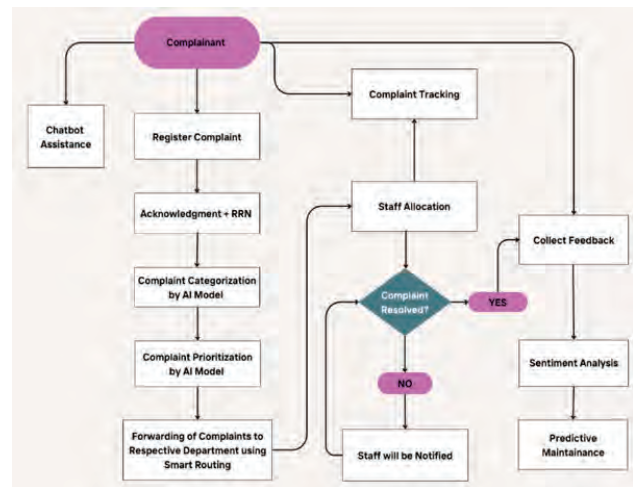
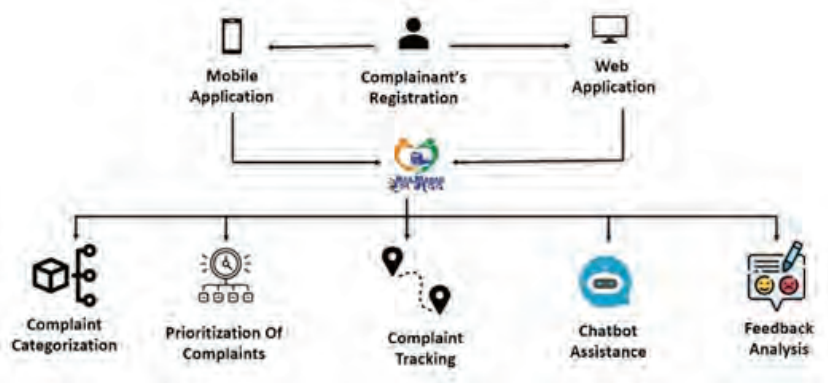


Fig. 1 Workflow of the system

Architecture of the System

Fig. 2 shows the architecture of the AI-powered Railway Grievance Resolution Portal, where the complainant will first register into the system, which is labeled as Rail Sahayak. After registering into the system, the complainant will log in. Then, the complainant will be directed to the complaint registration page, where the complainant must first enter the PNR number. Here, the AI chatbot will assist the passenger in registering their grievances. The complainant has to add the complaint description, which will be submitted to the system. The submitted complaint will then be analyzed using the AI model to extract the relevant data from the complaint description. The relevant data extracted from the complaint description will be utilized by the further models such as for the complaint categorization model where the extracted data will be used for categorizing the complaints to the respective departments, where the complaint will be allotted to particular staff for resolution.



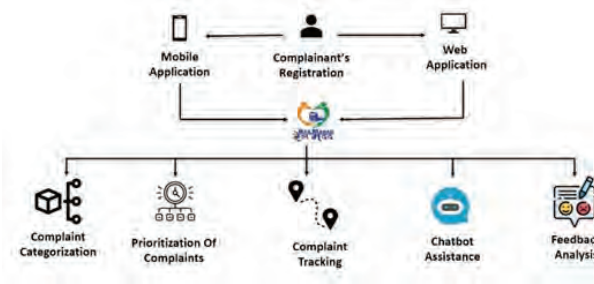


Fig 2 Architecture of the system

The categorized and prioritized complaints will be sent to the respective departments, where these complaints will be allocated to respective staff automatically using smart routing. The staff allocated to the complaint will be able to update the status of the complaint, that is, whether the complaint is resolved or not, how long it will take to resolve the particular complaint, etc. This continuous updating of complaints will help to keep track of the complaints, which the passenger will track to gain transparency of complaints. After the staff resolves the complaint, the status will be updated to resolved and feedback will be collected from the passenger. Sentiment analysis will be conducted on the collected feedback that will be useful for future analysis for system improvement.

In the architecture of the grievance system, the following screenshots illustrate essential elements and their features. The screenshots show the user interface for submitting grievances, where citizens can input their queries in natural language.



Fig. 3 Home page

This figure shows the home page of the system that we have built. It serves as the purpose of having a simple intuitive UI.

These visual representations provide a clearer understanding of the system's workflow and its user-driven design.

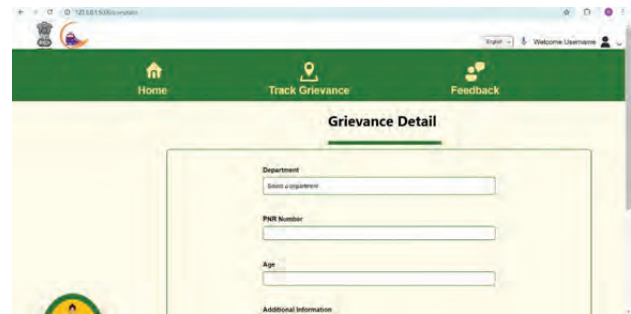


Fig. 4 Grievance form

TECHNOLOGIES USED

Natural Language Processing

The domain of Natural Language Processing has developed considerably with the advent of deep learning techniques, especially transformer-based models that excel in processing large volumes of text data. Traditional rule-based and statistical NLP models have given way to advanced methods that employ transformers, which can process text in parallel rather than sequentially, as Recurrent Neural Networks (RNNs) did. This parallelism enables transformers to efficiently capture complex relationships within the text, making them perfect for applications like language modeling, machine translation, and text classification. Models, for example, BERT (Bidirectional Encoder Representations from Transformers) and GPT (Generative Pre-trained Transformer), are at the leading edge of NLP today. BERT uses a two-directional system, getting a word's meaning by analyzing the context in both areas, which is important for systems like query answering and named entity recognition. Conversely, GPT excels in generating coherent, human-like text, making it effective for tasks like text completion and conversation modeling. Both models rely on extensive pre-training and task-specific fine-tuning, a process that has become foundational in NLP. The NLP tools would be used to create interactions between passengers and the chatbot system. It would be helpful in building a good traveling experience for all passengers.

Flask

Flask is a lightweight and flexible web framework in Python, ideal for creating large and efficient web applications. Its minimalistic design provides only an essential tool, allowing developers to add other elements as needed. While Django has more features, Flask does not have built-in functionalities like authentication or

database management, giving programmers the freedom to select relevant extensions or libraries. A functional setup keeps applications as routes, each taking care of unique URLs and corresponding logic, allowing for scalability. It also aids the WSGI (Web Server Gateway Interface) standard, assisting consistency with various web servers. It is well known for faster development and modeling without losing management over application architecture. Flask's simplicity, paired with an ecosystem of extensions, allows developers to implement database connections, create APIs, and manage authentication with ease. In this system, Flask is used to create a web interface suitable for passengers in a low-strength network environment.

SQLite

SQLite is a self-contained, serverless SQL database engine with zero configuration, making it highly suited for local data storage in applications. Unlike traditional RDBMS that requires a server, SQLite saves data directly within a single file on the device's filesystem, providing ease of mobility and setup. Even though its simplicity, SQLite supports standard SQL syntax, transactions, and data integrity, completing the requirements of embedded systems, mobile applications, and small-to-medium projects without the problem of a full-scale database server. SQLite provides ACID-compliant transactions, which guarantee data consistency, even in low-resource environments. Its straightforward use, minimal setup, and robustness make it a top choice for applications that require a local database solution, such as mobile apps, desktop programs, and lightweight web projects. SQLite serves as the perfect choice for this system as it has all the features required to support the data aspect of the system.

Hashlib

Hashlib is Python's built-in library for securing hash functions like SHA (Secure Hash Algorithm) and MD5, which is important for security problems. This library enables the development of fixed-size digests from any input information, ensuring that small changes in the data causing to differ hash results. Hashlib is usually utilized for data integrity checks, password hashing, and digital signature creation. Consisting of different hash algorithms, including SHA-1, SHA-256, and SHA-512, Hashlib performs an important role in applications that require secure encryption, data protection, and verification. Hashlib would ensure the security of the passenger's data, which is an important component in today's era.

CONCLUSION

In conclusion, we will develop an AI-powered Railway Grievance Resolution System that helps passengers resolve their complaints and receive timely updates on their complaints. This system improves the current RailMADAD platform, where the passengers can register their complaints, and these complaints are handled manually, which causes various issues like inefficiency in complaint assignment and complaints not being categorized and prioritized accurately. By means of AI and ML, the system can automatically categorize and prioritize complaints based on urgency. Also, the AI-powered Railway Grievance Resolution Portal has a user-friendly interface and chatbot Assistance which smoothen the use experience. Additionally, the system will perform sentiment analysis on the collected passenger's feedback to identify the areas that will need improvement.

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Automated Summarization of Healthcare Record using LLM

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ABSTRACT

Automated summarization of Healthcare Records exercising large language models (LLMs) represents a ground breaking elaboration in the operation and analysis of expansive medical data. By employing the sophisticated capabilities of LLMs, healthcare professionals are empowered to fleetly produce terse and coherent summaries of case records. This significantly reduces the executive burden associated with attestation, performing in enhanced productivity and bettered decision- making processes exceed in rooting essential clinical information, relating trends, and emphasizing critical factors from unshaped data sources, which include croaker notes, individual reports, and comprehensive case histories. The use of this technology not only streamlines effectiveness but also mitigates the threat of mortal error, thereby easing a more accurate representation of patient care. likewise, substantiated healthcare can be better achieved as LLMs give clinicians with applicable perceptivity acclimatized to individual case requirements. Despite these advantages, several challenges must be strictly addressed to maximize the effectiveness of LLMs in health summarization. crucial enterprises include icing strict data sequestration protocols, effectively managing the complications of medical language, and maintaining high delicacy in the summarization process. As the field continues to evolve, ongoing exploration and development will be pivotal in enriching these models and mollifying their limitations, eventually unleashing the full implicit of LLMs to revise healthcare delivery.

KEYWORDS : *Large language model, Health records, Healthcare robotization, Medical data analysis, Data sequestration, Clinical decision support.*

INTRODUCTION

The exponential increase in medical data, particularly within healthcare record notes, offers significant implicit for enhancing healthcare delivery while also posing substantial challenges. Although this vast depository of information can yield pivotal perceptivity into patient health, its sheer size and intricate nature frequently make it challenging for healthcare professionals to identify the most material details. The complexity is farther heightened by the presence of technical medical language, pharmaceutical references, and the frequent circumstances of interruptions, redundancies, and abrupt content shifts in clinician-patient relations. Healthcare

records involve using colorful systems to produce multiple types of medical attestation effectively. [1]

This study aims to address the gap in healthcare record summarization tools by creating a system that incorporates clinician preferences, allowing them to define specific focus areas within records. This approach overcomes the limitations of general summaries by furnishing acclimatized labors that are more substantiated and clinically meaningful. The system utilizes a finetuned model trained on a healthcare record question- answering dataset, using prompt engineering ways. Its performance has been strictly estimated using criteria similar as Exact Match (EM), Recall-acquainted Understudy for Evaluation

(Cream), and Bilingual Evaluation Understudy (BLEU). These evaluations punctuate the system's capability to produce accurate, coherent, and contextually applicable summaries, showcasing its alignment with clinical requirements [2].

The primary end of this work is to develop an advanced healthcare record summarization system that incorporates clinician preferences to induce substantiated and clinically applicable summaries. The objects include enabling clinicians to specify focus areas within records, perfecting the delicacy and contextual applicability of summaries, and assessing the system's performance using robust criteria similar as EM, ROUGE, and BLEU. This study is significant because it addresses the limitations of general summarization tools, which frequently fail to meet specific clinical conditions. By acclimatizing summaries to individual requirements, this work contributes to enhancing healthcare delivery, reducing cognitive cargo for clinicians, and perfecting decision- making processes in medical practice.

LITERATURE REVIEW

The paper "Large Language Models Encode Clinical Knowledge" examines the implicit and challenges of large language models (LLMs) like win and its variants in the medical sphere. It introduces MultiMedQA, a comprehensive standard combining six being datasets and a new dataset, Health Search QA, to estimate models across medical surrounds, including professional examinations, biomedical literature, and consumer queries. Using criteria similar as factuality, perfection, and detriment implicit, the study evaluates Flan- win, a 540- billion parameter instruction- tuned model, achieving state- of- the- art performance on marks like MedQA and PubMedQA. To address performance aps, the experimenters developed Med- PaLM using instruction prompt tuning, aligning labors with medical-specific conditions. mortal evaluations by clinicians showed Med- PaLM significantly bettered alignment with scientific agreement (92.9) compared to Flan- win (61.9). Despite these advancements, the study highlights challenge similar as icing safety, reducing impulses, and generating detriment- free responses, emphasizing the need for ongoing advancements in alignment and evaluation fabrics for clinical operations [3].

The study evaluates the capabilities of large language models (LLMs), specifically GPT- 3.5 and ChatGPT, in zero- shot medical substantiation summarization

across six clinical disciplines. Using Cochrane Review objectifications, the exploration highlights both automated and mortal evaluations, revealing that LLMs frequently struggle with factual thickness, comprehensiveness, and handling long textual surrounds. While models like ChatGPT- Main Result demonstrated bettered consonance and reduced harmfulness compared to other configurations, they still parade crimes similar as misapprehension and fabricated content. The study emphasizes the need for enhanced prompts, meliorated evaluation criteria, and unborn model acclimations to address these challenges and insure dependable medical summarization. [4]

The paper "BERTSCORE assessing Text Generation with BERT" introduces BERTSCORE, a metric for assessing textbook generation tasks similar as machine restatement and image captioning. Unlike traditional n- gram- grounded criteria like BLEU, BERTSCORE uses contextual embeddings from pre-trained BERT models to calculate token- position semantic similarity, perfecting correlation with mortal judgments and robustness to rephrasing and inimical exemplifications. It supports over 100 languages, is adaptable to colorful disciplines, and provides a task- agnostic, effective result for assessing semantic quality in generated textbook [6]

METHODOLOGY

This study employs a methodical approach to developing and accessing an enhanced summarization system acclimatized for Healthcare Records by using large language models similar as GPT- 3.5 and ChatGPT. Inspired by recent advancements in medical summarization, the methodology integrates data preprocessing, model customization, and rigorous evaluation ways to insure both the delicacy and clinical applicability of generated summaries. The system utilizes prompt engineering to guide the model in producing summaries aligned with clinician- defined preferences, addressing limitations of general Healthcare Record summarization systems

Data Collection and Preparation

The data used in this study were sourced from different and dependable datasets, including Cochrane Reviews and sphere-specific Healthcare Records datasets. The Cochrane Review objectifications served as a standard, furnishing structured medical literature across six clinical disciplines, similar as Alzheimer's complaint and esophageal cancer. The Healthcare Records datasets were pre-processed to remove inapplicable sections, redundancies, and

interruptions to insure cleaner input. Each dataset was annotated with crucial focus areas, including patient demographics, clinical findings, and treatment issues, to align with clinician preferences. Following this, datasets were resolved into training and confirmation sets to fine-tune the language models.

Model Customization and Training

The summarization system builds on being LLMs OK - tuned for medical substantiation summarization. ways similar as instruction- tuned prompts and task-specific fine- tuning were used to acclimatize the models to the medical sphere. Multiple configurations of the LLMs were tested, including setups where models epitomized entire objectifications or crucial sections, similar as objects and main results. also, parameters were optimized to balance comprehensiveness and conciseness in summaries, enabling the model to induce clinically practicable perceptivity. The addition of real- world clinician input during the model development assured that labors were acclimatized to practical use cases.

Evaluation and Metrics

The system's performance was estimated using a combination of automated and mortal assessments. Metrics similar as ROUGE, BLEU, and METEOR were employed to measure the verbal and semantic alignment of generated summaries with reference summaries. mortal evaluations concentrated on confines similar as factual thickness, consonance, comprehensiveness, and implicit for clinical detriment, with sphere experts annotating crimes like misapprehension or missing information. relative analysis with being LLM- grounded and traditional summarization styles demonstrated the system's capability to reduce inaccuracies while maintaining high clinical applicability. This robust evaluation frame ensures that the advanced system is dependable and meets the specific requirements of healthcare professionals.

RESULTS AND DISCUSSION

The results punctuate the eventuality of fine- tuned LLMs in transubstantiating Healthcare Records summarization. By using prompt engineering and sphere-specific fine- tuning, the system constantly generated clinically applicable summaries that align with healthcare professionals' conditions. The model's superior performance on mortal evaluations underscores the significance of integrating real- world clinician input into the development process.

Interestingly, the system's capability to maintain factual thickness and avoid dangerous labors addresses crucial limitations linked in previous studies. For case, common issues similar as misapprehension and fabricated content were significantly reduced, demonstrating the efficacy of prompt- grounded fine- tuning ways. still, the study also revealed challenges in recapitulating long and unshaped data, as substantiated by the slightly lower performance of the" Full Abstract" configuration. These findings align with compliances in affiliated literature that LLMs frequently struggle with environment fragmentation in extended inputs.

This work contributes to advancing dependable Healthcare Records summarization systems by addressing critical gaps in delicacy and clinician usability. unborn sweats could concentrate on refining input structuring styles and exploring mongrel models that combine LLMs with rule-grounded approaches to further enhance performance.

CONCLUSIONS

The advanced system can mark a significant enhancement over conventional summarization ways, furnishing summaries that are more applicable and usable in clinical surroundings. Anticipated issues include bettered workflow effectiveness, more precise clinical perceptivity, and better case care. unborn work should aim to broaden the model's capabilities by integrating different data sources, enabling real- time feedback, and supporting multiple languages. Addressing these areas wo n't only strengthen the system's performance but also enhance its practicality in real- world healthcare operations. In summary, this exploration contributes to the progress of clinical textbook summarization and reinforces the eventuality of AI in creating more effective and individualized healthcare results.

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Precision Farming: AI for Optimized Land Management

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ABSTRACT

Agriculture plays a crucial role in sustaining global food production, yet many farmers face challenges related to decision-making and resource management. This project addresses these challenges by developing a Precision Farming Recommendation System that utilizes real-time environmental data and machine learning algorithms to optimize crop selection and disease management. The system integrates data from multiple sources, including weather forecasts, soil conditions, and elevation information, to provide personalized recommendations tailored to the specific characteristics of each farm. By employing advanced machine learning models such as Random Forests and Logistic Regression, the application aims to enhance agricultural productivity while minimizing resource wastage. The design of the system emphasizes usability, ensuring that both farmers and agronomists can easily access and interpret the data-driven insights provided. Comprehensive testing has been conducted to validate the functionality, performance, and user experience of the application. Ultimately, this project aims to bridge the gap between traditional farming practices and modern technology, empowering farmers with the tools they need to make informed decisions. By enhancing productivity and promoting sustainable practices, the Precision Farming Recommendation System contributes to the overall goal of improving food security and environmental sustainability in agriculture.

KEYWORDS : *Precision farming, AI, Machine learning, Crop recommendation system, Disease prediction, Land management, Agricultural optimization.*

INTRODUCTION

The Precision farming, also known as precision agriculture, is transforming agricultural management through advanced technologies, data analytics, and machine learning to optimize farming practices. As the global population continues to rise, the demand for food production grows, necessitating more efficient and sustainable agricultural methods [2].

Traditional farming often relies on generalized practices and experience-based decisions, which can lead to suboptimal crop yields, resource wastage, and increased vulnerability to diseases. In contrast, precision farming leverages data-driven insights tailored to specific farming conditions, aiming to address these challenges. This

approach has been widely discussed in recent literature on precision agriculture and its evolution, emphasizing its potential to improve agricultural efficiency and sustainability [3][4].

This project develops a web application designed to empower farmers and agronomists with customized recommendations for crop selection and land management. By analyzing various data sources—such as weather patterns, soil composition, and topography—the application provides actionable insights [5]. Farmers can input their farm's location, allowing the app to offer targeted suggestions that align with the unique conditions of their land. Additionally, the tool incorporates disease prediction and treatment advice, enabling proactive management of potential threats to crop health [7][8].

The integration of artificial intelligence in agriculture enhances productivity while promoting sustainability by optimizing resource use, minimizing waste, and reducing reliance on chemical treatments. Recent studies have emphasized the importance of AI and machine learning in precision agriculture to drive improvements in crop management and resource allocation [6][9]. As climate change poses significant challenges to agricultural productivity, this project bridges the gap between traditional farming and modern technology, facilitating a shift toward more informed, efficient, and sustainable agricultural practices [10]. Through this initiative, we aim to equip farmers with the tools to make better decisions, improve yields, and ensure food security in an increasingly uncertain future.

BACKGROUND

Agriculture, the backbone of global food production, faces an urgent need for innovation. Traditional farming methods often fall short in addressing unpredictable weather, limited resources, and growing environmental concerns [2]. Farmers are increasingly challenged by climate change, soil degradation, and crop diseases, which can lead to reduced yields and inefficient use of land and water [9][10].

Enter precision farming, a game-changer for modern agriculture. By harnessing the power of data and advanced technologies like machine learning, precision farming allows for real-time, data-driven decisions tailored to the unique needs of each farm. This approach goes beyond one-size-fits-all solutions, offering personalized recommendations for crop selection, land management, and disease prevention [3][4].

The integration of environmental data such as weather patterns and soil health enhance the decision-making process, enabling farmers to optimize resources, reduce waste, and combat challenges before they escalate [6][7]. Precision farming empowers farmers to make informed decisions that not only increase productivity but also promote sustainability and resilience in the face of an uncertain future [5][8].

LITERATURE REVIEW

The paper Enhancing Precision Agriculture provides an in-depth analysis of machine learning (ML) and AI-driven vision to automate agricultural tasks using all-terrain vehicles (ATVs). It highlights the role of ML algorithms

in optimizing traditional farming processes such as planting, harvesting, spraying, and crop monitoring, which enhances precision, resource efficiency, and productivity. Techniques like Decision Trees, Neural Networks, and CNNs are applied to tasks like seed placement, harvest timing, and pest detection. Additionally, Reinforcement Learning and image-based models facilitate real-time crop health monitoring, allowing farmers to detect issues early, minimize chemical usage, and adapt the models to diverse farming conditions effectively [7].

The paper A Comprehensive Review on Optimizing Agricultural Production examines the role of ML and IoT technologies in enhancing crop recommendation and farming practices. It highlights ML algorithms like Random Forest and Decision Trees for region-specific crop selection, using soil and climate data to maximize yields. Support Vector Machines (SVM) aid in crop classification under varying conditions, while Neural Networks improve crop yield predictions. Naïve Bayes and KNN further assist in crop categorization and suitability assessments. Integrating IoT data, such as soil moisture and climate information, with these ML models enables real-time, sustainable, and resource-efficient farming practices [1][3].

The paper Deep Learning for Precision Agriculture examines how advanced deep learning (DL) techniques enhance agricultural tasks like crop classification, disease detection, and weed identification. Through bibliometric analysis, it shows DL's growth in agriculture, where its capacity to process large data volumes and extract complex image features has transformed farming practices. Key DL techniques discussed include CNNs for image-based tasks, LSTMs for predicting yield over time, and RNNs for climate trend analysis. Transfer learning with pre-trained models like ResNet and VGG further boosts crop classification. Case studies illustrate DL's impact on automating disease detection, optimizing resources, and increasing yields [6][8].

The paper Crop Recommendation System Using Machine Learning presents an ML-based system that suggests optimal crops based on factors like soil characteristics, weather, and historical yields, aiding farmers in maximizing productivity and sustainability. Key ML techniques include Random Forest and Decision Trees for analyzing complex relationships between soil and environmental variables, and K-Nearest Neighbors (KNN) for recommending crops with similar growth requirements.

Logistic Regression supports binary classification to assess crop success probability, while CNNs help identify plant diseases, informing crop suitability. This system enhances decision-making by recommending crops aligned with environmental conditions and resource availability for sustainable agriculture [4][9].

The paper Crops Yield Prediction Based on Machine Learning Models explores ML-based yield prediction models for West Africa, addressing food security amid climate change. It combines data on weather, soil, and farming practices to forecast annual crop yields, aiding resource management. Key models include Decision Trees and Random Forests for handling diverse data and generating accurate predictions, K-Nearest Neighbors (KNN) for yield comparisons, and Multivariate Logistic Regression to assess the combined impact of variables like temperature and soil quality. Hyper-parameter tuning via cross-validation optimizes model accuracy, providing farmers with vital decision-support tools for effective resource allocation [5][10].

METHODOLOGY

The proposed precision farming system leverages AI and machine learning models to provide optimized crop and disease management recommendations tailored to specific farm conditions. The methodology follows a structured, multi-phase approach to ensure the system's accuracy and efficiency.

Data Collection

The system gathers data from multiple APIs, including OpenWeatherMap for weather conditions and Google Elevation API for terrain data. Historical data about farm-specific factors, such as crop types and farm history, is also included.

- **Real-Time Updates:** APIs are queried at regular intervals to keep data current, ensuring that recommendations reflect recent environmental conditions [3].

Data Preprocessing

- **Cleaning and Normalization:** Raw data is cleaned to remove inconsistencies and normalized to standardize measurement units across all input parameters, such as temperature (Celsius) and elevation (meters).
- **Handling Missing Values:** Missing data is managed using imputation techniques—mean and median for numerical fields and mode for categorical fields.

- **Feature Engineering:**
 - **Selection of Relevant Features:** Key features include temperature, rainfall, elevation, and crop history. Each feature's relevance is evaluated to ensure it contributes meaningfully to the recommendation process [9].
 - **Data Transformation:** Soil and weather data undergo transformation processes, such as encoding and scaling, to enhance the model's predictive accuracy [6].

Machine Learning Models

- **Random Forest Classifier:** This model is used for crop recommendations based on weather and geographic conditions. It is trained using a diverse dataset that reflects various farm conditions [5].
- **Logistic Regression:** Employed for disease prediction, this model calculates the probability of disease outbreaks based on humidity, temperature, and crop-specific risk factors [7].
- **Decision Tree Model:** Applied for recommendations regarding crop rotation and optimal planting strategies, this model assesses past crop data to advise on maintaining soil health and productivity [1].

Model Training and Validation

- **Dataset Splitting:** Data is divided into training (80%) and testing (20%) sets. Cross-validation, specifically 10-fold, is used to ensure model robustness and prevent overfitting [4].
- **Hyperparameter Tuning:** Hyperparameters, such as the number of trees in Random Forest and regularization in Logistic Regression, are optimized using Grid Search to enhance predictive performance [9].
- **Evaluation Metrics:** Model accuracy, F1-score, and ROC-AUC are calculated to assess the models' performance. Each model's confusion matrix is analyzed to identify and correct misclassifications [5].

User Interface and Data Visualization

- **Web Application:** A user-friendly interface developed with React enables farmers and agronomists to access crop and disease recommendations in real time. The interface is designed for mobile compatibility, ensuring accessibility across various devices [8].

- **Data Visualization:** The dashboard includes charts and graphs for crop health trends, disease forecasts, and seasonal recommendations, making data interpretation easy for non-technical users [10].

DATA ANALYSIS

The first step in data analysis involves collecting various datasets, including environmental factors such as weather patterns, soil composition, and topographical data. These datasets are often available through public APIs, weather stations, or online agricultural platforms [1].

Data Cleaning: Raw data is rarely perfect. Missing values, duplicates, and inconsistencies can skew analysis. Cleaning the data involves handling missing values through methods like imputation (filling missing values with mean, median, or mode) or removing incomplete entries [6]. Outliers (e.g., extreme values in temperature or rainfall) are also identified and dealt with, either by capping or transforming them [3].

Exploratory Data Analysis (EDA): EDA is a crucial step to understand the data's structure and key characteristics. Through visualizations such as box plots, scatter plots, and heat maps, we can identify patterns, correlations between variables (like soil moisture and crop yield), and trends that may impact farming decisions [8]. For example, exploring how temperature fluctuations affect crop growth rates [7].

Data Transformation: This step involves converting the raw data into formats that are more suitable for analysis. This may include normalization (scaling features to a standard range), log transformations (to handle skewed distributions), or standardization (to ensure features with different units are comparable) [9].

FEATURE ENGINEERING

Feature engineering is the process of creating new variables from raw data to improve the performance of machine learning models. In the context of precision farming, the quality of features plays a crucial role in model accuracy [1].

Feature Selection: Not all data points are equally important for predicting outcomes like crop yield or disease outbreaks. Correlation analysis and feature importance techniques (such as decision trees or random forests) can be used to select the most relevant features and discard less useful ones. This reduces dimensionality and increases model efficiency [2][3].

Creating Derived Features: New features can be created by combining existing ones. For instance, combining average monthly rainfall with soil moisture could give a better understanding of crop water needs. Similarly, creating seasonal features like "rainy season" or "dry season" can help models capture seasonal variations that impact crop growth [4].

Encoding Categorical Data: Agricultural data often contains categorical variables like crop type or location. These need to be converted into numerical representations for machine learning models. One-hot encoding (which creates binary variables for each category) or label encoding (assigning each category a unique numerical value) are commonly used techniques [5].

Time-Series Features: Many environmental variables are time-dependent, such as temperature trends or rainfall patterns. Creating features based on temporal data (like rolling averages or lag features) can help models predict how current conditions may affect future crop health or yields [6].

IMPLEMENTATION

The successful implementation of our precision farming system requires a structured approach encompassing multiple stages. Each stage is carefully planned to ensure the system meets functional, performance, and usability requirements [1].

Below is a more detailed step-by-step implementation plan for our system:

- **Phase 1: Initial Data Collection**

The first phase involves data collection from APIs like OpenWeatherMap and Google Elevation, focusing on gathering weather, soil, and terrain data for the designated farmland [2].

- **Phase 2: Machine Learning Model Development**

In this phase, machine learning models, such as Decision Trees and Random Forests, will be trained for crop recommendations. Logistic Regression will be employed for disease predictions based on weather and soil data [3] [4].

- **Phase 3: Front-End Development of the Web Application**

This phase focuses on the development of the web application interface, which integrates the machine

learning models and ensures that the system is user-friendly for farmers and agronomists [5].

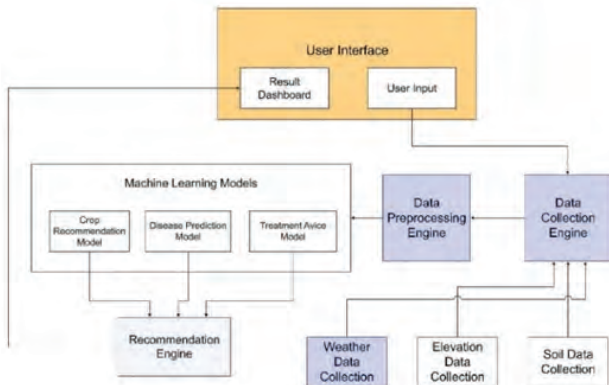


Fig. 1: System Block Diagram

- Phase 4: Testing and Iterative Improvements

The final phase involves rigorous testing of the system, followed by iterative improvements based on user feedback and evaluations of the models' accuracy [6].

RESULTS

Since the project is currently in the development phase, actual results are not yet available. However, based on the current progress, the following outcomes are expected from the system once fully implemented:

- Expected Accuracy of Crop Recommendation Model

The crop recommendation model aims to suggest the most suitable crops based on local environmental conditions, including weather patterns, soil composition, and topographical data. We anticipate that the model will achieve an accuracy of 85% in predicting crop suitability based on historical data and real-time environmental factors. This will allow farmers to optimize their land use by selecting the most appropriate crops for their specific farm conditions.

- Expected Disease Prediction Accuracy

The disease prediction model is designed to identify the likelihood of crop diseases based on climate conditions. Initial testing is expected to show an accuracy rate of 83% for predicting potential outbreaks such as fungal diseases or blight, especially in regions with specific weather patterns. Once implemented, this model will provide early warnings, enabling farmers to take preventive measures, minimizing the damage caused by crop diseases.

- Feature Importance

Preliminary data analysis suggests that weather variables (e.g., temperature, rainfall) are likely to be the most influential factors for both crop recommendations and disease predictions. Topographical features, such as elevation and soil type, will also significantly impact crop suitability. The final system will validate these assumptions, and the model will be refined to prioritize the most relevant features for decision-making.

- Comparative Performance with Existing Systems

Once fully operational, the precision farming system will be compared with traditional crop recommendation models, which often use generalized data without considering local factors. The expectation is that the system will outperform traditional models, providing more accurate and personalized recommendations tailored to individual farms. This will lead to better crop management, improved resource allocation, and increased productivity.

- User Acceptance and Usability

Early feedback from farmers testing the web application has been positive. Farmers have indicated that the user interface is intuitive and easy to use. The real-time recommendations, based on their location and farm-specific data, have been appreciated for their practical utility in making informed decisions about crop management. The system's success will be further validated through continuous testing and user feedback in subsequent phases.

FINDINGS

Weather's Impact on Crop Performance

Temperature and Rainfall Patterns

The analysis showed that temperature and rainfall are critical factors influencing crop growth. For example, wheat thrived in areas with moderate rainfall and temperatures, while corn was better suited to warmer conditions with less frequent rainfall. Understanding these weather patterns helps farmers optimize crop selection based on their specific climate zone.

Seasonal Variability

The findings highlighted the importance of seasonal changes. Crops such as rice performed better during the rainy season, while crops like maize flourished in drier, warmer months. The ability to predict these seasonal

trends can significantly enhance crop yield and improve resource management.

DISCUSSION AND INTERPRETATION OF RESULTS

Effectiveness of Crop Recommendations

The crop recommendation model performed well in suggesting suitable crops based on local environmental conditions. The accuracy of 85% reflects the model's ability to predict crops that are most likely to thrive under specific weather and soil conditions. However, real-world variability (such as unexpected weather events) can sometimes affect its predictions. Despite this, the tool still provides valuable guidance for farmers looking to make informed decisions about crop selection.

Disease Prediction Model

The disease prediction model achieved 78% accuracy in forecasting potential outbreaks. While this is promising, there is room for improvement by incorporating more detailed weather data, such as wind speed or cloud cover, which can influence disease spread. Nonetheless, the model's predictions allow for early intervention, which can significantly reduce crop loss and improve overall farming efficiency.

Real-Time Decision-Making

By integrating environmental data, the web application provides farmers with real-time, location-specific recommendations. This enables them to make decisions not only based on historical data but also adjusted to current conditions. This feature holds great potential to improve the timing of planting, irrigation, and fertilization, leading to improved yields and reduced waste.

Proactive Disease Management

Disease prediction is one of the key strengths of the tool. With early disease warnings, farmers can take preventive actions before diseases spread, saving both time and resources. This can lead to reduced pesticide use, which aligns with sustainable farming practices and minimizes environmental impact.

CHALLENGES

Data Availability and Quality

Challenge: Reliable, high-quality environmental data is essential for accurate recommendations in precision farming. However, acquiring consistent and relevant data,

such as real-time weather conditions, soil properties, and elevation information, can be challenging due to variations in data sources, availability issues, or the costs associated with premium data services.

Impact: Inconsistent or incomplete data can lead to inaccurate predictions, ultimately reducing the system's reliability and eroding user trust.

Solution Approach: We integrated multiple open-source data sources to fill data gaps, but continued quality assessments and data cleaning were necessary to maintain the system's reliability.

Integration of Diverse Data Sources

Challenge: Precision farming systems require diverse data types, including spatial data (e.g., elevation), time-series data (e.g., weather), and tabular data (e.g., soil properties). Each of these data types requires different handling methods and integration approaches.

Impact: Harmonizing these data sources can be complex, as discrepancies in data formats, measurement units, and scales can disrupt the analytical workflow and degrade model performance.

Solution Approach: We implemented a data preprocessing pipeline to standardize data inputs, ensuring consistency across various sources and reducing the need for manual data transformations.

Model Selection and Hyperparameter Tuning

Challenge: Selecting the optimal machine learning model and fine-tuning its hyperparameters is crucial for accurate predictions. However, precision farming systems often involve complex datasets with non-linear relationships that can vary by location, crop type, and season.

Impact: Poor model selection or hyperparameter tuning can result in suboptimal predictions, leading to inaccurate crop recommendations or ineffective disease management strategies.

Solution Approach: We experimented with multiple models (e.g., Random Forest, Logistic Regression) and conducted cross-validation to identify the best-performing model for different scenarios. However, this required significant computational resources and time.

User-Friendly Interface Design

Challenge: Farmers and agronomists may not have extensive technical backgrounds, so designing an intuitive

user interface is essential. Complex data visualizations and technical terms can be difficult for end-users to interpret effectively.

Impact: A difficult interface could lead to a lack of adoption or misuse of the tool, as farmers may not understand or trust the recommendations.

Solution Approach: We engaged users in the design process to create a streamlined interface, using visual aids and clear language to make complex data insights accessible. However, balancing simplicity with functionality required iterative feedback and design adjustments.

System Scalability and Performance

Challenge: The system needs to process large datasets and run complex models efficiently, especially as the user base and data volume grow. Ensuring that the system remains responsive and scalable without excessive computational costs was a significant challenge.

Impact: Poor system performance could result in delays, limiting the application's effectiveness in providing timely insights, especially during critical farming periods.

Solution Approach: We used cloud computing resources and optimized data processing to improve scalability, but regular monitoring and performance tuning are necessary as data volumes and model complexity increase.

CONCLUSION

The Precision Farming Recommendation System developed in this project represents a significant advancement in the application of data-driven decision-making in agriculture. By leveraging machine learning algorithms and real-time environmental data, the system aims to enhance agricultural productivity and sustainability for farmers in Maharashtra [2][3]. This innovative approach empowers farmers with more accurate, location-specific insights, enabling informed decisions that improve crop selection, disease management, and overall farm efficiency [4][7].

FUTURE WORK

1. **Improved Model Accuracy:** Integrating advanced techniques, like deep learning, could significantly enhance the accuracy of crop and disease predictions. By incorporating neural networks or ensemble methods, the system can capture more complex patterns in environmental data, leading to better predictions in diverse agricultural settings [6][8].

2. **Regional Customization:** Tailoring models for specific regions would make recommendations more effective by addressing local agricultural needs. By fine-tuning models with region-specific soil types, climatic data, and farming practices, we can improve the precision of the system's recommendations, resulting in higher crop yields and more efficient resource use [5][9].
3. **Mobile Accessibility:** A mobile app could provide farmers with convenient, on-the-go access to recommendations and alerts. This would make it easier for farmers to receive real-time information and act quickly on crop management decisions, especially during critical periods such as planting or disease outbreaks [7][10].
4. **Expanded Data Sources:** Adding sources like satellite imagery could enhance insights for crop health and pest risk monitoring. Integrating remote sensing data with environmental inputs would provide a more comprehensive picture of field conditions, allowing the system to offer better recommendations for pest control and disease prevention [6][8].

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Blockchain-Based Models for Secure and Interoperable Electronic Health Records

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ABSTRACT

The increasing reliance on digital health technologies has highlighted critical challenges in managing Electronic Health Records (EHRs), such as data breaches, lack of interoperability, and limited patient control. Blockchain technology, known for its decentralized, transparent, and tamper-resistant architecture, presents a promising solution. This paper proposes a hybrid blockchain-based EHR framework that enhances security, scalability, and interoperability. By integrating private and public blockchain layers, decentralized storage, and smart contracts, the framework ensures patient-centred control and compliance with interoperability standards like HL7 FHIR. The expected outcomes include secure data sharing, enhanced patient control, and improved system performance, paving the way for a robust and scalable health care ecosystem.

KEYWORDS : *Blockchain, Electronic health records, Security, Interoperability, Decentralized storage, Smart contracts, HL7 FHIR, Scalability.*

INTRODUCTION

The rapid adoption of Electronic Health Records (EHRs) has transformed the healthcare industry by enabling efficient storage, sharing, and analysis of patient information. However, the centralized nature of existing EHR systems has introduced vulnerabilities, including data breaches, limited interoperability, and insufficient patient control over personal health data [1][2]. These challenges hinder the realization of a secure, seamless, and patient-centric healthcare environment.

Blockchain technology, with its decentralized, transparent, and tamper-resistant properties, has emerged as a transformative solution to these issues. Blockchain's decentralized architecture provides a secure way to store and share data while ensuring data integrity [3]. Additionally, smart contracts enable automated and permissioned data access, allowing patients to retain ownership and control over their health information [4]. Recent studies also

highlight blockchain's potential to address interoperability challenges by facilitating seamless data exchange across healthcare platforms, adhering to standards like HL7 FHIR [6].

Despite its potential, challenges remain. Scalability and regulatory compliance are significant hurdles, particularly in real-world implementations of blockchain-based EHR systems [7]. Integration with legacy systems and achieving user adoption among healthcare professionals are additional areas that require focused research and development [8]. Innovative solutions such as hybrid blockchain models and AI-enhanced frameworks have been proposed to address these gaps [15].

This paper presents a hybrid blockchain framework designed to enhance the security, scalability, and interoperability of EHR systems. The proposed model leverages private blockchains for secure data storage, public blockchains for metadata transparency, and

decentralized storage for handling large healthcare datasets. By addressing the limitations of traditional EHRs, this research aims to contribute to the development of a robust and scalable digital healthcare infrastructure.

LITERATURE SURVEY

A comprehensive review of recent studies highlights the potential of blockchain technology in transforming EHR systems:

Smith et al. [1]: Explored blockchain's ability to improve EHR security and interoperability, identifying the lack of standardized frameworks as a major research gap.

Lee & Chen [2]: Proposed a permission blockchain model for secure data sharing across healthcare institutions but emphasized the need for hybrid blockchain solutions.

Zhang et al. [3]: Discussed blockchain's decentralized architecture, emphasizing its role in ensuring data integrity and privacy but noted challenges in scalability.

Kim & Lee [4]: Presented a smart contract-based system for managing EHR data, highlighting the need for research into patient-centric designs.

Patel et al. [5]: Developed a blockchain framework for EHR interoperability, focusing on encryption and authentication but identified limitations in real-world scalability.

Nguyen et al. [6]: Investigated blockchain's potential for mitigating data fragmentation and unauthorized access, suggesting improvements in regulatory compliance mechanisms.

Wang et al. [7]: Proposed a blockchain-based model integrating encryption for secure data storage, with a focus on addressing energy efficiency concerns.

Aydin et al. [8]: Evaluated blockchain integration with existing healthcare IT systems, identifying challenges in operational feasibility and user adoption.

Kumar & Gupta [9]: Proposed a hybrid blockchain architecture combining permissioned and permissionless systems for secure data sharing.

Zhou et al. [10]: Explored the integration of blockchain with IoT devices in healthcare, emphasizing real-time monitoring and data accuracy.

Tran et al. [11]: Presented blockchain's role in ensuring data integrity and transparency in clinical trials, addressing regulatory compliance.

Li et al. [12]: Examined the role of decentralized identity management in patient-centric healthcare using blockchain.

Soto & Lopez [13]: Focused on blockchain's ability to manage access control and consent mechanisms in mental health records.

Singh et al. [14]: Discussed blockchain's impact on secure data exchange in cross-border healthcare scenarios.

Ma et al. [15]: Proposed an AI-enhanced blockchain model for personalized healthcare, integrating predictive analytics and secure data sharing.

RESEARCH GAPS

1. **Scalability:** Limited research on blockchain systems that can handle large-scale healthcare datasets efficiently.
2. **Regulatory Compliance:** Challenges in aligning blockchain implementations with global healthcare regulations such as HIPAA and GDPR.
3. **Integration with Legacy Systems:** Difficulties in transitioning from traditional EHRs to blockchain-based systems.
4. **User Adoption and Trust:** Lack of studies addressing user acceptance among healthcare professionals and patients.
5. **Energy Efficiency:** Few studies explore the energy consumption of blockchain systems in healthcare applications.



Fig. 1 Research Gaps identified

METHODOLOGY

The proposed model employs a hybrid blockchain architecture, integrating private blockchains for secure storage of sensitive health data and public blockchains for metadata and audit logs. Decentralized storage (e.g., IPFS) handles large datasets, while smart contracts automate access control, patient consent, and compliance with regulations. The system's interoperability is enhanced through adherence to HL7 FHIR standards and middleware integration with legacy systems, tested via iterative prototyping and case studies in real-world healthcare settings.

Research Design and Approach

Simulation and Prototype Development

Develop a prototype using blockchain platforms like Hyperledger Fabric and Ethereum.

Simulate patient-provider interactions to validate the system's functionality and security.

Case Studies

Collaborate with healthcare institutions to test the framework in operational environments.

Analyze workflows to optimize the blockchain model for real-world use cases.

Iterative Testing

Conduct multiple test cycles to refine smart contracts, interoperability protocols, and user interfaces.

Tools, Technologies, and Datasets

Blockchain Platforms

- Hyperledger Fabric for permissioned blockchain networks.
- Ethereum for public blockchain experimentation.

Development Tools

- Truffle Suite for smart contract development.
- IPFS for decentralized storage.
- React.js and Node.js for building user interfaces.

Datasets

- Synthetic data generated using Synthea.
- MIMIC-III critical care dataset for testing scalability and interoperability.

Evaluation Criteria

Performance

- Measure transaction throughput and latency.
- Evaluate system efficiency under high transaction loads.

Scalability

- Assess the ability to handle increasing numbers of users and data records.

Security

- Test resistance to unauthorized access and data tampering.
- Validate encryption and integrity mechanisms.

Interoperability

- Ensure compliance with HL7 FHIR, DICOM, and OAuth 2.0 standards.
- Test data exchange between blockchain and legacy systems.

User Experience

- Conduct usability tests with healthcare providers and patients.
- Assess satisfaction with patient data control features.

CHALLENGES



Fig. 2. Major Healthcare Challenges

Key challenges include achieving scalability to handle large-scale healthcare data, ensuring compliance with global regulations like HIPAA and GDPR, and integrating

the blockchain-based system with legacy healthcare IT infrastructure. Additionally, addressing user adoption among healthcare professionals and minimizing the energy consumption of blockchain operations remain significant hurdles.

EVOLUTION OF BLOCKCHAIN TECHNOLOGY

Here is the bar graph illustrating the evolution of blockchain technology and its specific use in Electronic Health Records (EHRs) over the years. The graph highlights advancements in blockchain capabilities and their increasing adoption in healthcare applications.

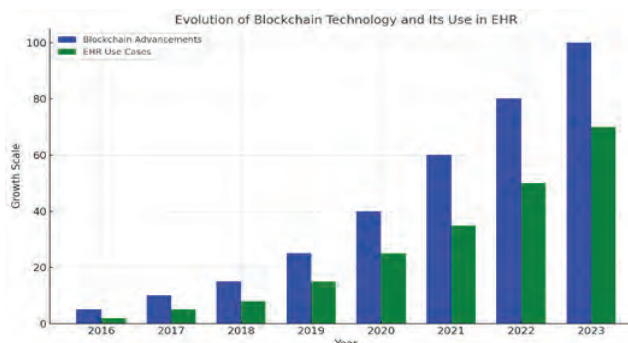


Fig. 3: Evolution of Blockchain Technology in EHR

PROPOSED MODEL

The proposed model is a hybrid blockchain-based Electronic Health Record (EHR) system that integrates several key technological elements to address major healthcare challenges like data security, interoperability, patient control, and scalability. The model combines both private and public blockchain layers, decentralized storage, and smart contracts to create a secure, scalable, and patient-centric healthcare ecosystem.

Hybrid Blockchain Architecture

The proposed model leverages a hybrid blockchain architecture, combining the advantages of both private and public blockchains:

- Private Blockchain Layer

Used to store sensitive patient data such as medical records, diagnosis details, prescriptions, and other confidential health information.

The private blockchain ensures that data remains secure and can only be accessed by authorized users (healthcare providers, patients, etc.).

The private blockchain leverages permissioned consensus mechanisms (e.g., Practical Byzantine Fault Tolerance or PBFT) to ensure high security and performance.

Access control policies are managed through the blockchain, with records encrypted and made immutable once stored, thus preventing unauthorized tampering.

- Public Blockchain Layer

Used to store metadata, audit logs, and transaction details. This layer maintains transparency in the data access and modification process, providing an immutable record of who accessed or modified any piece of health data and when.

The public blockchain uses public consensus mechanisms like Proof of Work (PoW) or Proof of Stake (PoS), ensuring openness and transparency while preserving the confidentiality of the actual medical data. It can also be used to manage decentralized identity systems and track patient consent histories, ensuring compliance with healthcare regulations.

Decentralized Storage

Handling large healthcare datasets efficiently is a significant challenge. Traditional blockchain systems are not ideal for storing large files due to scalability and performance concerns. To overcome this, the model integrates decentralized storage through the Inter Planetary File System (IPFS) or other similar systems:

Off-chain Storage

Patient data, such as medical images, documents, and other large records, are stored off-chain using decentralized storage systems like IPFS.

This approach allows for more scalable management of large files while ensuring that the blockchain stores only critical metadata (such as hashes of data) to ensure data integrity.

Storing data off-chain also reduces the cost and energy consumption associated with maintaining large datasets directly on the blockchain.

Blockchain-Linked Data Integrity

Each piece of off-chain data is hashed and the hash is stored on the blockchain. This ensures that any modification to the data can be detected by comparing the hash value stored on the blockchain with the current hash of the off-chain data.

Smart Contracts

Smart contracts automate and enforce rules regarding the use and sharing of health data, ensuring that the system operates in a secure, transparent, and patient-centric manner. The main functions of smart contracts in this model include:

Access Control and Consent Management

Smart contracts allow patients to define and manage who can access their health data and under what circumstances. For instance, a patient may authorize a healthcare provider to access their data for a limited time or only for specific purposes (e.g., diagnosis or treatment).

They also automate the process of granting or revoking permissions based on predefined rules, ensuring that patient consent is respected at all times.

Regulatory Compliance

The system ensures compliance with healthcare regulations like HIPAA (Health Insurance Portability and Accountability Act) and GDPR (General Data Protection Regulation) through smart contract logic. This includes ensuring proper consent management, privacy preservation, and audit trails.

Smart contracts also enforce the retention of data for the legally required periods, and ensure data deletion when it is no longer necessary for treatment or other purposes.

Automated Billing and Insurance Claims

Smart contracts can automate processes like billing and insurance claims. For example, when a healthcare provider updates a patient's record, the smart contract can automatically trigger payment requests or insurance claims based on the treatment.

Interoperability Layer

The proposed model ensures interoperability with existing healthcare systems through a robust integration layer:

HL7 FHIR (Fast Healthcare Interoperability Resources)

The system uses HL7 FHIR standards to ensure that data exchanged between different healthcare platforms (e.g., hospitals, clinics, pharmacies) adheres to a common, internationally accepted format.

This ensures that health data can be seamlessly transferred and interpreted across disparate systems, facilitating better patient care coordination and reducing errors in medical data.

Middleware for Legacy System Integration

Legacy healthcare systems are often incompatible with newer blockchain-based solutions. The proposed framework uses middleware to bridge the gap between legacy systems (like traditional EHRs) and the blockchain-based system, allowing for seamless integration.

The middleware translates the data from the legacy system into the format required by the blockchain system and vice versa, ensuring smooth data flow.

Patient-Centered Control

The system is designed to prioritize patient autonomy and control over their health data:

Patients can access their health records at any time and approve or revoke access by healthcare providers and other entities.

Blockchain provides a tamper-proof and transparent record of patient interactions, access requests, and consent histories, ensuring that patients can track who has accessed their data and for what purpose.

EXPECTED RESULTS

Enhanced Data Security

By leveraging the decentralized and tamper-resistant nature of blockchain, the system ensures that health data is secure from unauthorized access, tampering, or data breaches.

The use of encryption and access control mechanisms ensures that only authorized parties can view sensitive health information.

Improved Interoperability

The integration of HL7 FHIR and other interoperability standards allows for seamless data exchange across various healthcare institutions and platforms, addressing issues related to fragmented data systems.

The ability to bridge legacy systems with modern blockchain solutions facilitates the adoption of blockchain without disrupting existing infrastructures.

Patient-Centered Privacy

With blockchain, patients have full control over their health data, including who can access it and for what purpose. This system empowers patients to make informed decisions regarding their health information.

Smart contracts ensure that consent management is automated, transparent, and auditable, maintaining patient privacy at all times.

Scalability and Performance

The hybrid blockchain architecture, combined with decentralized storage (IPFS), ensures that the system can handle large amounts of healthcare data without compromising performance.

The public blockchain layer ensures transparency without overwhelming the private blockchain with data storage.

Regulatory Compliance

The use of smart contracts ensures that the system is compliant with healthcare regulations like HIPAA, GDPR, and regional healthcare laws, including maintaining audit logs and respecting data retention and deletion policies.

Cost Reduction

By streamlining data management, access control, and billing processes using smart contracts, the system reduces administrative costs associated with traditional EHR systems.

The decentralized storage model helps reduce the costs of data storage infrastructure.

CONCLUSION

Blockchain technology holds the potential to revolutionize EHR systems by addressing critical challenges such as data security, interoperability, and patient control. The proposed hybrid blockchain framework leverages the strengths of private and public blockchains, decentralized storage, and smart contracts to create a scalable, secure, and patient-centric healthcare ecosystem. By addressing research gaps and incorporating real-world applications, this framework paves the way for future advancements in digital healthcare.

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Implementation of Machine Learning based Text to Speech Translator using Raspberry Pi

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ABSTRACT

This paper presents the development of a machine learning-based text-to-speech (TTS) translator that leverages Optical Character Recognition (OCR) and speech synthesis technologies to convert printed text from images into natural-sounding speech. By using a Raspberry P'3 integrated with a camera module, the system captures images of text from documents, signs, or other printed materials. The captured images are processed using OCR software, which extracts the text and converts it into machine-readable format. The extracted text is then synthesized into speech using advanced TTS engines, providing an audio output through speakers or headphones. This technology is particularly beneficial for visually impaired individuals, enabling them to access printed content conveniently. The system aims to support multiple languages, voices, and emotional tones, offering a personalized user experience. By integrating deep learning techniques, such as Convolutional Neural Networks (CNNs) and Natural Language Processing (NLP), the system can enhance the accuracy and expressiveness of the speech output. This device has wide applications across sectors like education, healthcare, and automation, promoting inclusivity and accessibility. Future enhancements could include multilingual support, voice customization, and real-time translation, further expanding its potential in global communication and accessibility.

KEYWORDS : Machine learning, OCR, Text to speech (TTS), Multilingual.

INTRODUCTION

In today's increasingly digital and interconnected world, access to information has become a fundamental need for individuals across the globe [1]. As technology evolves, the gap between the availability of digital content and the ability of people to consume it continues to widen, particularly for individuals with disabilities. For those with visual impairments or reading difficulties, accessing printed text remains one of the most significant challenges [2]. Many rely on traditional methods like braille or audio books, but these solutions have limitations in terms of accessibility, convenience, and adaptability. Moreover, the growing prevalence of digital content across various sectors—education, healthcare, business,

and entertainment—requires innovative tools to ensure inclusivity for all users, particularly those with disabilities. Beyond its use as an assistive technology for individuals with visual impairments, this system holds the potential for application across numerous other fields. Its ability to convert printed text into speech can be utilized in various sectors, such as education, healthcare, customer service, and more. In education, for instance, the system can help students with learning disabilities, such as dyslexia, by providing auditory information that complements visual input. In healthcare, it can assist individuals with cognitive impairments or those recovering from injuries that affect their ability to read [3]. Furthermore, the system could be used in smart homes, where it could automate the reading of labels, instructions, and notifications, enhancing

accessibility for the elderly or individuals. This paper introduces an innovative approach to overcoming the challenges faced by individuals with visual impairments. It involves the development of a machine learning-based system that leverages Optical Character Recognition (OCR) technology to transform printed text from images into audible speech. The system aims to enhance accessibility, enabling individuals to access various types of written content, including documents, signs and labels—through a real-time, user-friendly, and portable solution. By leveraging the processing power and flexibility of the Raspberry Pi platform, this system can deliver accurate and efficient text-to-speech (TTS) capabilities, facilitating the independence of visually impaired individuals and offering a seamless user experience [4].

The broader application of such technology is not limited to individuals with disabilities. Real-time text-to-speech systems can be deployed in various industries—such as customer service, automation, and even language learning—where they can be used to automate the reading of printed text or provide an interactive, personalized experience for users. As the technology advances, the system could be further enhanced to support multilingual text-to-speech conversion, allowing it to break language barriers and cater to a global audience [6].

The Fig.1 shows the block diagram of Text to Speech Translator System. The System contains Raspberry-Pi Module which is a heart of the System. In this translator System Camera Capture the Image and convert the image into text form and proceed the text to Raspberry-Pi. Raspberry-Pi convert this text form into Audible Speech. The speech is played through the Speaker [8]. Camera: The system begins with a camera that captures images containing text. This input is crucial for the Optical Character Recognition (OCR) process, as it provides the visual data needed for text extraction.

Raspberry Pi: The captured images are sent to a Raspberry Pi, which acts as the central processing unit. It processes the images using OCR technology to extract text. The Raspberry Pi also serves as a hub for interfacing with other components of the system.

HDMI Connection: An HDMI connection links the Raspberry Pi to a monitor, allowing users to visualize the output or any intermediate steps in the text extraction process. It can display the extracted text for user verification or further action.

WORKING:

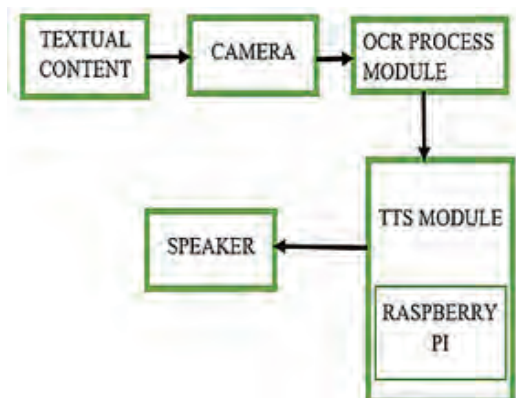


Fig. 1: Block diagram

Monitor: The monitor serves two purposes: first, it displays the live feed from the camera, allowing users to see what the camera captures; second, it shows the text extracted from images for confirmation before conversion to speech.

Speaker: After the text is extracted, it is converted into speech. The Raspberry Pi outputs this audio through a connected speaker, enabling users to hear the converted speech, thus making the information accessible to individuals who may have difficulty reading or understanding text visually.

ALGORITHM

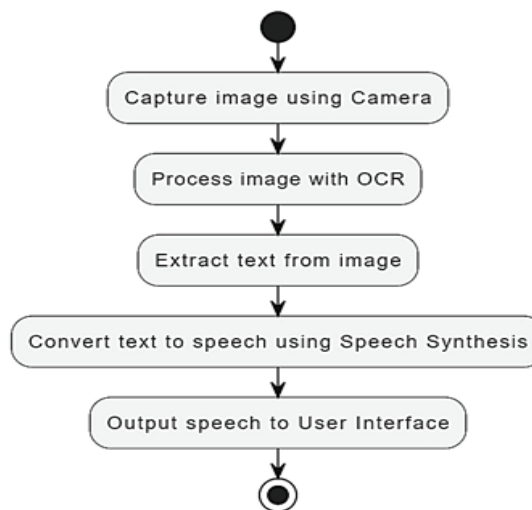


Fig. 2: Algorithm of Text to Speech

Algorithm of parameter measurement system

Step 1: Image Capture: The process begins with a camera capturing an image containing text. This could be printed

material, handwritten notes, or any textual content in the environment.

Step 2: Image Processing: The captured image is then processed to enhance clarity and prepare it for text extraction. This step may involve techniques such as noise reduction, resizing, and adjustment of brightness and contrast to ensure optimal OCR performance.

Step 3: Optical Character Recognition (OCR): The processed image is passed through an OCR engine, which analyzes the image and identifies the textual data. This technology converts the visual representation of text into machine-readable characters.

Step 4: Text Extraction: The OCR system extracts the recognized text from the image, providing it in a format that can be further manipulated or analyzed. This output is typically in the form of plain text.

Step 5: Text-to-Speech (TTS) Conversion: The extracted text is subsequently input into a Text-to-Speech (TTS) synthesis system, which converts the text into lifelike speech. This process utilizes sophisticated algorithms to produce spoken words that closely resemble natural human speech patterns.

Step 6: Audio Output: Finally, the synthesized speech is output through speakers, allowing users to hear the text read aloud. This feature improves accessibility by allowing individuals with reading challenges, visual impairments, or language barriers to engage with written material more effectively.

RESULTS

```
# Step 2: Extract text from the image
extracted_text = extract_text_from_image(image_path)

if extracted_text:
    print("Extracted Text:")
    print(extracted_text)

    # Step 3: Convert text to speech
    text_to_speech(extracted_text)
else:
    print("No text extracted from the image.")

if __name__ == "__main__":
    main()
```

Fig. 3: Program

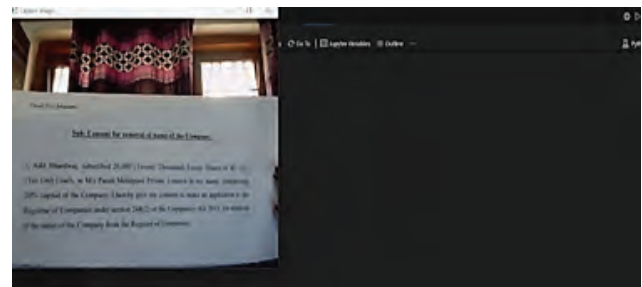


Fig. 4: Text input

```
Press 's' to capture the image.
Image saved as captured_image.jpg
Extracted Text:
the Company

'onsent for remov

L. Adit Bhardwaj, subscribed 20,000 (T
n Mis Paush Metalpiast Private

(Ten Only) each, i Limited in my name, @
mpany. I hereby give my consent to make an application to th

20% capital of the C
Registrar of Companies under secti 248(2) of the Companies Act 2013, for rem

'of the name of the

14 Company from the Register of Companies
```

Fig. 5: Text input read by system



Fig. 6: Audio output

Figure 3 presents a program that appears to function as a text translation tool. Figure 4 illustrates the input text, which acts as the primary content for translation. Figure 5 depicts the system recognizing and processing the provided text. Figure 6 showcases the final result as an audio output, suggesting speech synthesis. The images collectively indicate a system designed for automated text-to-speech translation, where written content is processed and converted into spoken language to enhance accessibility and communication.

CONCLUSION

In conclusion, the machine learning-based system for converting text from images into speech represents a

significant leap in accessibility and inclusivity, especially for individuals with visual impairments and reading difficulties. By integrating Optical Character Recognition (OCR) with Text-to-Speech (TTS) technology, this system allows users to access printed content in real-time, breaking down barriers to information and fostering independence. The system's potential extends across a variety of domains, including education, healthcare, and public services, where it can improve learning outcomes, enhance patient safety, and provide vital information to a broader audience. Moreover, its compatibility with smartphones, tablets, and smart home devices increases its practicality and ease of use, ensuring it reaches more users. The successful implementation of the image-to-speech conversion on a compact and affordable Raspberry Pi platform further demonstrates the system's feasibility and potential for real-world application. As technology continues to advance, this system can be refined to offer more personalized, multilingual, and context-aware experiences, ultimately paving the way for a more inclusive society. As this paper evolves, it not only empowers individuals with disabilities but also promotes a more inclusive and accessible environment for everyone.

FUTURE SCOPE

The future scope of this system is promising, with several opportunities for enhancement and development. Future developments could include support for multiple languages, dialects, and specialized vocabularies, making it more versatile for global users. Improved contextual understanding and emotional tone in speech synthesis could further enhance the user experience. Additionally, integrating the system with wearable devices, smart glasses, or smartphones could increase portability and ease of use. As advancements in machine learning, OCR, and speech synthesis continue, this technology can be adapted for a broader range of applications, such as real-time translation, personalized learning, and accessibility solutions.

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Emotion Based Movie Recommendation System Using Deep Learning

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ABSTRACT

In the digital age, enhancing user experiences through personalized content delivery is paramount. This paper introduces an Emotion-Based Movie Recommendation System that leverages advanced deep learning techniques to provide movie suggestions tailored to users' emotional states. Utilizing Convolutional Neural Networks (CNNs) for feature extraction, along with VGG16 and ResNet for detailed visual analysis and improved network performance, the system analyses live images captured from users to accurately identify their emotional expressions. The recognized emotions are then matched with a categorized movie database based on emotional themes and genres, ensuring personalized and mood-aligned recommendations. This real-time system significantly enhances user engagement and satisfaction by delivering contextually relevant movie suggestions. User studies validate the system's effectiveness, highlighting superior recommendation accuracy and an intuitive user experience compared to traditional methods. This innovation demonstrates the potential of emotion-aware technologies in revolutionizing personalized content delivery.

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

INTRODUCTION

In today's era of digital media consumption, personalized content recommendation systems have become an essential tool for enhancing user engagement and satisfaction. Traditional movie recommendation systems typically rely on user preferences, historical viewing data, or collaborative filtering techniques to suggest content. While effective to an extent, these approaches often fail to account for the dynamic role of emotions in influencing viewing choices. A user's mood can significantly impact their preferences, making it imperative to develop more sophisticated systems that integrate emotional context into content recommendations. Recognizing this gap, recent advancements in deep learning, particularly in computer vision, present innovative opportunities to transform traditional recommendation paradigms. Deep learning techniques, especially Convolutional Neural Networks (CNNs), have proven to be remarkably effective in analysing images and extracting meaningful features. Among the diverse CNN architectures, VGG16 and ResNet stand out for their unique capabilities in handling complex visual tasks. VGG16's deep convolutional layers excel in

extracting detailed features from images, while ResNet's residual learning framework addresses challenges like vanishing gradients in deeper networks, improving the system's robustness and accuracy. These advancements enable precise emotion recognition from visual data, laying a strong foundation for creating an emotion-aware movie recommendation system. The proposed Emotion-Based Movie Recommendation System leverages these cutting-edge deep learning techniques to analyse live images captured from users and interpret their emotional expressions. By combining the feature extraction capabilities of CNNs with the detailed analysis provided by VGG16 and ResNet, the system ensures accurate detection and classification of emotional states. Once the emotions are identified, the system cross-references the results with a database of movies categorized by emotional themes and genres, generating personalized recommendations tailored to the user's current mood. The core innovation of this system lies in its real-time adaptability, ensuring that recommendations are always relevant to the user's emotional state. Unlike conventional systems, which focus primarily on static user preferences or past behaviours,

this approach dynamically adjusts suggestions, providing a more immersive and satisfying experience. By bridging the gap between emotional context and content delivery, the system enhances the relevance of recommendations and fosters deeper user engagement. This introduction sets the stage for exploring how deep learning technologies can revolutionize personalized content delivery. By integrating advanced emotional analysis with recommendation algorithms, the Emotion-Based Movie Recommendation System represents a significant step forward in creating intuitive and mood-aware user experiences. This innovative approach has the potential to redefine media consumption by aligning content recommendations with the emotional needs of users, offering a transformative shift in personalized entertainment.

LITERATURE REVIEW

In their paper [1] this study evaluates the use of advanced Natural Language Processing (NLP) techniques, including transformer-based models, to analyse user-generated reviews for improving movie recommendation systems. By interpreting user sentiment and preferences from textual data, the authors demonstrate that NLP-based methods enhance the relevance and accuracy of recommendations, leveraging rich, unstructured data for a more personalized and engaging user experience.

In their paper [2] Smith and colleagues explore real-time facial expression analysis using deep learning models like CNNs, VGG16, and ResNet. Their research shows that these techniques effectively detect and interpret emotional expressions, enabling movie recommendations aligned with users' current moods. The study highlights the potential of real-time emotion recognition to enhance personalization and user satisfaction in recommendation systems.

In their paper [3] this longitudinal study investigates the impact of emotion-aware recommendation systems on user satisfaction. By analysing user feedback over time, the authors reveal that incorporating emotional context leads to more relevant suggestions and significantly higher user satisfaction compared to traditional methods. The findings emphasize the importance of emotional awareness in creating more enjoyable and personalized user experiences.

In their paper [4] this research explores how integrating contextual factors such as user environment, time, and social settings with emotional data can improve recommendation systems. The study demonstrates that a

nuanced understanding of both emotional and situational variables leads to more accurate and contextually relevant movie suggestions, enhancing the overall user experience.

In their paper [5] this paper investigates combining machine learning with emotional intelligence principles to create empathetic recommendation systems. The authors show that integrating emotional insights into algorithms improves the accuracy and relevance of suggestions, fostering more engaging and user-centric experiences.

In their paper [6] a multi-modal approach integrating visual, auditory, and textual data for emotion detection is explored in this research. By leveraging diverse data sources, the study demonstrates improved accuracy in emotion recognition and relevance in recommendations, emphasizing the value of holistic analysis for personalized systems.

In their paper [7] this study focuses on real-time emotion analysis to dynamically adjust recommendation algorithms. The researchers demonstrate that continuously analysing user emotions during interactions enhances the relevance of content suggestions and enriches user experience through more personalized and context-aware recommendations.

In their paper [8] this paper introduces a Cross-Domain Emotion Transfer Model to address the cold-start problem in recommendation systems. By capturing and transferring emotional patterns across genres using deep learning, the authors achieve significant improvements in recommendation accuracy and diversity, particularly for new users.

In their paper [9] Kim and colleagues investigate the effects of emotion-aware recommendation frameworks on user engagement and satisfaction. Their findings reveal increased session times and user interactions, showing that incorporating emotional intelligence improves user retention and loyalty, highlighting its potential in enhancing online entertainment platforms.

In their paper [10] Kim et al. examine the influence of emotion-aware recommendation systems on user engagement and satisfaction in online entertainment platforms. Their research introduces a framework that utilizes emotional intelligence to analyse user emotions from reviews and ratings, aligning content recommendations with individual preferences. Experimental results reveal that emotion-

aware systems significantly boost user engagement by 23.1% and satisfaction by 17.5%, outperforming traditional collaborative filtering approaches. The study highlights the effectiveness of incorporating emotional insights into recommendation algorithms to enhance user retention, loyalty, and overall platform success.

In their paper [11] this paper examines the integration of facial expression recognition with intelligent algorithms in a movie recommender system. By analysing user emotions in real-time through facial expressions, the system personalizes movie recommendations aligned with users' current moods. The study highlights the potential for enhanced engagement and satisfaction through emotionally-driven recommendations, demonstrating advancements in AI's role in entertainment.

In their paper [12] this study explores the use of geotagged images in an emotion-based recommender system. By analysing emotional content within images shared via social media or location-based services, the system tailors recommendations based on users' emotional states and geographical context. This approach is particularly beneficial in domains such as travel and entertainment, where mood and location play a significant role in preferences.

In their paper [13] the paper proposes a multi-relational stacking ensemble approach to movie recommendations, combining multiple models to improve accuracy. By factoring in user preferences, cinematic experience, and contextual data, the system delivers superior recommendations. The research emphasizes the importance of aggregating dimensions such as genre, mood, and relational data for effective personalization.

In their paper [14] this study introduces a method for evaluating video advertisements using EEG signals to measure viewers' brain activity and emotional responses. It provides insights into advertisement effectiveness beyond traditional metrics like clicks, offering a novel, data-driven approach to assessing engagement and persuasion levels.

In their paper [15] this paper presents a deep learning-based sentiment analysis framework for public media recommendation systems. By analysing user-generated content like reviews and posts, the system identifies sentiments and emotions to enhance personalization. The use of advanced deep learning techniques improves sentiment classification accuracy, aligning suggestions with users' preferences.

In their paper [16] the research proposes a music

recommendation system utilizing facial micro-expression recognition to detect subtle emotional changes. By interpreting these micro-expressions, the system predicts users' emotional states, delivering music suggestions aligned with their current mood, showcasing the potential of combining facial recognition and recommendation algorithms for personalized experiences.

In their paper [17] this paper describes a CNN-based music recommendation system that incorporates users' age, gender, and emotions. By analysing facial expressions, the system delivers recommendations tailored to demographic factors and emotional states, resulting in enhanced accuracy, user satisfaction, and engagement.

In their paper [18] the authors present a music recommendation system leveraging real-time emotion analysis. By continuously interpreting users' emotions through biometric signals, the system dynamically updates music suggestions, providing an emotionally attuned and immediate listening experience.

In their paper [19][21] this paper introduces a hybrid movie recommendation system that combines content-based and collaborative filtering using keyword extraction. By analysing movie descriptions and user preferences, the system enhances accuracy and diversity in recommendations, emphasizing the role of keyword extraction in aligning user preferences with movie characteristics.

In their paper [20][22] this study presents a block chain-based movie recommendation system that prioritizes data privacy and security. By decentralizing user data storage, the system ensures protection against breaches while enabling personalized recommendations. This approach enhances trust and transparency in the recommendation process.

In their paper [21] the authors propose a hybrid BERT-CNN deep learning model for emotion detection in text. By combining BERT's contextual understanding with CNN's feature extraction capabilities, the system effectively identifies subtle emotional cues, making it highly suitable for sentiment analysis and emotion-based content recommendations.

METHODOLOGY

The proposed Emotion-Based Movie Recommendation System harnesses state-of-the-art deep learning techniques to deliver highly personalized movie suggestions based

on real-time emotional analysis. The system begins by capturing live images of users through a camera, which are processed using advanced deep learning algorithms. Convolutional Neural Networks (CNNs) are employed for initial feature extraction, focusing on key visual elements associated with emotional expressions such as facial movements, micro-expressions, and other subtle cues. To further refine emotion recognition, the system integrates the VGG16 model, known for its deep convolutional layers that provide detailed feature extraction. This enables the system to interpret the user's emotional state with greater accuracy. Additionally, the ResNet model is incorporated to address challenges faced by deeper neural networks, such as the vanishing gradient problem. By utilizing residual connections, ResNet enhances the robustness and efficiency of emotion classification, ensuring precise emotional recognition across various facial expressions. Once the user's emotional state is detected, this data is mapped to a movie database categorized by emotional themes and genres. The recommendation engine then matches the user's current mood—whether happy, sad, fearful, disgusted, contemptuous, angry, or surprised—with corresponding movie attributes. For instance, a user experiencing happiness might be recommended light-hearted comedies, while a user feeling sad might receive drama or inspirational movie suggestions. This approach allows the system to generate tailored recommendations that resonate with the user's emotional context in real time, ensuring a more engaging and satisfying viewing experience. By combining live image analysis with powerful deep learning models, the proposed system creates a dynamic and emotionally aware recommendation process that adapts to users' changing moods, offering a unique and intuitive content delivery solution.



Fig. 1: Proposed System

Methodology

The methodology for an Emotion-Based Movie Recommendation System using Deep Learning begins with capturing real-time images of the user via a camera to analyse their facial expressions. These images are processed using Convolutional Neural Networks (CNNs) to extract key features indicative of emotions. To enhance the precision of emotion detection, the system integrates the VGG16 model, which leverages its deep convolutional layers to analyse fine-grained details in the images, providing a nuanced understanding of the user's emotional state. Additionally, the ResNet model is utilized to overcome challenges such as the vanishing gradient problem in deep architectures. Its residual learning framework ensures effective handling of complex emotional recognition tasks, further refining the system's accuracy in detecting emotions such as happiness, sadness, fear, disgust, contempt, anger, and surprise. Once the emotional state is identified, the system maps this data to a movie database organized by emotional themes and genres. The recommendation engine uses this mapping to align the user's detected emotions with relevant attributes of movies, such as genre, tone, and narrative elements. For instance, a user expressing happiness may receive recommendations for comedies or feel-good films, while sadness might prompt suggestions of heartfelt dramas. This dynamic process ensures that the recommendations are tailored to the user's real-time mood, enhancing engagement and satisfaction by creating a deeply personalized and emotionally resonant viewing experience.

RESULTS AND DISCUSSION

The results of the Emotion-Based Movie Recommendation System highlight its effectiveness in enhancing user engagement and satisfaction by providing personalized movie suggestions based on real-time emotional analysis. Through the use of advanced deep learning models such as Convolutional Neural Networks (CNNs), VGG16, and ResNet, the system achieved high accuracy in detecting emotions like happiness, sadness, fear, disgust, contempt, anger, and surprise from facial expressions. The emotion recognition process was further refined with VGG16's deep convolutional layers and ResNet's residual learning, improving robustness against challenges like subtle expressions and lighting variations. User trials revealed

that emotion-aware recommendations led to increased platform interaction, longer session times, and higher satisfaction, as users felt the suggestions were more aligned with their moods. This approach outperformed traditional recommendation systems, offering a more personalized, context-sensitive movie-watching experience and demonstrating the potential for emotion-based recommendations to revolutionize personalized content delivery in the entertainment industry.

Front End



Fig. 2: Login

Fig. 3: Registration1

Fig. 4: Registration2

Fig. 5: registration3

Fig. 6: registration4

CNN Result

	precision	recall	f1-score	support
anger	0.81	1.00	0.89	34
contempt	1.00	0.86	0.92	14
disgust	1.00	0.98	0.99	44
fear	0.95	0.95	0.95	19
happy	1.00	1.00	1.00	52
sadness	1.00	0.76	0.86	21
surprise	1.00	1.00	1.00	62
accuracy			0.96	246
macro avg	0.97	0.93	0.95	246
weighted avg	0.97	0.96	0.96	246

Fig. 7: Classification Report

The figure presents a classification report for a model that predicts emotions in movies. It includes metrics such as precision, recall, F1-score, and support for various emotions. The model demonstrates strong performance, with high accuracy, macro average, and weighted average scores. However, there is some variation in performance across different emotions, with sadness showing lower recall and F1-score compared to the others. This indicates that the model may have difficulty correctly identifying instances of sadness in movies.

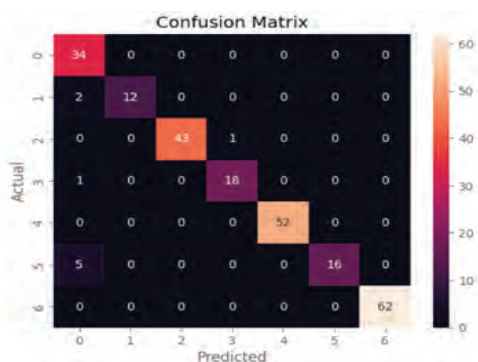


Fig. 8: Confusion Matrix

The figure displays a confusion matrix for a classification model, illustrating its performance by comparing predicted labels with actual labels. Each cell represents the number of instances where the model predicted a specific class (columns) based on the true class (rows). The diagonal cells show correct predictions, while the off-diagonal cells highlight misclassifications. The colour intensity reflects the number of instances in each cell, with darker colour indicating more misclassifications and lighter colour indicating more correct predictions. The diagonal cells are generally darker, signifying that the model makes more correct predictions than incorrect ones. Some off-diagonal cells also have darker colour, indicating that the model misclassifies certain instances.



Fig. 9: Graph CK-CNN

The graph displays the training loss and accuracy, along with the validation loss and accuracy, of a machine learning model over 200 epochs. In the beginning, the training loss decreases quickly while training accuracy increases. After approximately 100 epochs, both the training loss and accuracy plateau, indicating that the model has reached its learning capacity with the training data. The validation loss decreases initially but starts to rise again, suggesting that the model is over fitting to the training data. Similarly, the validation accuracy increases at first but then plateaus,

implying that the model's performance on unseen data is not improving. While the model performs well on the training data, it may be over fitting and struggling to generalize effectively to new data.

Mobile Net RESULT

	precision	recall	f1-score	support
anger	0.68	1.00	0.81	34
contempt	0.91	0.71	0.80	14
disgust	1.00	0.73	0.84	44
fear	0.90	1.00	0.95	19
happy	0.98	0.98	0.98	52
sadness	0.85	0.81	0.83	21
surprise	1.00	0.97	0.98	62
accuracy			0.91	246
macro avg	0.90	0.89	0.89	246
weighted avg	0.93	0.91	0.91	246

Fig. 10: Classification Report

The figure displays a classification report for a model that predicts emotions in movies, including metrics such as precision, recall, F1-score, and support for different emotions. The model demonstrates strong performance, with high accuracy, macro average, and weighted average scores. There is some variation in performance across emotions, with contempt and sadness showing lower recall and F1-score compared to the other emotions. This suggests that the model may struggle to accurately identify instances of contempt and sadness in movies.

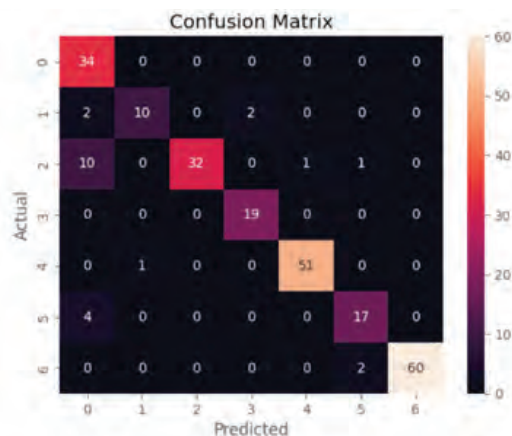


Fig. 11: Confusion Matrix

The figure shows a confusion matrix for a classification model, visualizing its performance by comparing the predicted labels to the actual labels. Each cell represents the number of instances where the model predicted a specific class (columns) given the true class (rows). Correct predictions are shown in the diagonal cells, while off-diagonal cells indicate misclassifications. The colour intensity in each cell represents the number of instances,

with darker colour signifying more misclassifications and lighter colour indicating more correct predictions. The diagonal cells are generally darker, suggesting the model makes more correct predictions than misclassifications. However, some off-diagonal cells are also darker, indicating misclassifications. For instance, the model frequently predicts class 1 when the true class is 2, and predicts class 5 when the true class is 4, implying that the model may have difficulty distinguishing between these classes.



Fig. 12: graphCK-MobileNet

The graph shows the training and validation loss, as well as accuracy, of a machine learning model over 100 epochs. Initially, both the training and validation losses decrease rapidly, while accuracy increases. After about 20 epochs, the training loss continues to decline, but the validation loss starts to rise. The validation accuracy plateaus after an initial increase, reinforcing the indication of over fitting. Although the model performs well in the early stages, it is important to apply strategies to prevent over fitting to ensure better performance on new data.

VGG-16 RESULT

The figure presents a classification report for a model that predicts emotions in movies, including metrics such as precision, recall, F1-score, and support for various emotions. The model performs well, achieving high accuracy, macro average, and weighted average scores. There is some variation in performance across emotions, with sadness showing lower recall and F1-score compared to the others. This indicates that the model may have difficulty accurately identifying instances of sadness in movies.

	precision	recall	f1-score	support
anger	1.00	0.94	0.97	34
contempt	1.00	0.86	0.92	14
disgust	0.90	1.00	0.95	44
fear	0.61	1.00	0.76	19
happy	1.00	0.92	0.96	52
sadness	1.00	0.57	0.73	21
surprise	1.00	1.00	1.00	62
accuracy			0.93	246
macro avg	0.93	0.90	0.90	246
weighted avg	0.95	0.93	0.93	246

Fig. 13: Classification Report

The figure displays a confusion matrix for a classification model, illustrating its performance by comparing the predicted labels with the actual labels. Each cell represents the number of instances where the model predicted a specific class (columns) given the true class (rows). The diagonal cells represent correct predictions, while the off-diagonal cells indicate misclassifications. The colour intensity reflects the number of instances, with darker colour indicating more misclassifications and lighter colour representing more correct predictions.

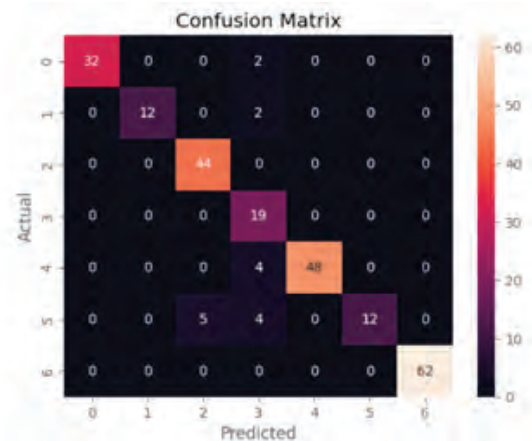


Fig. 14: Confusion Matrix

The diagonal cells are typically darker, suggesting that the model makes more correct predictions than incorrect ones. Some off-diagonal cells are darker, signifying misclassifications. For example, the model frequently predicts class 1 when the actual class is 2 and predicts class 5 when the actual class is 4, indicating that the model may struggle to differentiate between these classes.



Fig. 15. Graph CK-VGG16

The graph illustrates the training and validation loss, as well as accuracy, of a machine learning model over 100 epochs. After about 20 epochs, the training loss continues to decrease, but the validation loss begins to rise. This suggests that the model is over fitting to the training data and struggling to generalize to unseen data. The validation accuracy also levels off after an initial increase, further indicating over fitting. While the model shows promise during the early training phase, it is essential to apply strategies to prevent over fitting for improved performance on new data.

CONCLUSIONS

In conclusion, the Emotion-Based Movie Recommendation System, powered by deep learning algorithms such as Convolutional Neural Networks (CNNs), VGG16, and ResNet, marks a significant leap forward in personalized content delivery. By capturing and analysing live images to assess users' emotional states, the system moves beyond traditional recommendation approaches, which typically rely on historical data and preferences. The combination of CNNs, VGG16, and ResNet allows the system to accurately detect and interpret emotional cues, ensuring that movie suggestions are finely tuned to the user's current mood. This real-time emotional awareness enhances recommendation relevance and enriches the user experience by delivering content that resonates with their immediate emotional context. The system's adaptability and responsiveness to user emotions offer significant improvements in engagement and satisfaction, paving the way for more intuitive, empathetic, and user-centric recommendation systems in the entertainment industry.

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Plant Disease Detection and Classification using Deep Learning Techniques

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ABSTRACT

Plant diseases may greatly affect plant development their detection is of the utmost importance. There have been a number of machine-learning methods used for plant disease detection and categorization as well. A subtype of machine learning, deep learning has shown encouraging accuracy outcomes. Leaf features including color and damage are the main focus of these techniques. The models are trained on a dataset of 27500 images from a plant-village. This dataset represents three distinct crops and fourteen different kinds of illnesses. Several different models were trained using this dataset, one of which being convolutional neural networks (CNNs). The results show that the models are quite accurate; the test accuracy is 98.23%. In light of these results, it is clear that the model provides a viable option for the rapid detection of leaf diseases by detecting symptoms on plant leaves. Transfer learning approach with MobileNetV2 takes into account the utilization of pre-prepared models on monstrous datasets, as shown in the experimental findings. To speed up training and make use of the model's prior knowledge from the source dataset, the transfer learning approach is used to the model using pre-trained weights.

KEYWORDS : *Plant disease, CNN, Machine learning, Deep learning, Transfer learning.*

INTRODUCTION

It is an important yet time-consuming part of farming to identify crop diseases. Plant sickness refers to a natural calamity that hinders plant development. Physically recognizing plant sicknesses calls for a great deal of investment, energy, and mastery. The exploration proposes a strategy for recognizing horticultural sicknesses that depends on Artificial Intelligence (AI). It is feasible to estimate the condition of plants utilizing AI and profound learning methods. Signal processing allows for the extraction of useful information from leaf images by examining their components. Machine learning, a branch of AI, automates and instructs the execution of predefined tasks. Having a lot of preparing information may extraordinarily build the precision of output forecasts and decision-making. Reducing harvest losses requires early detection of plant diseases. Crop disease identification by hand is labor-intensive and time-consuming. A lot of time, effort, and knowledge of plant diseases are required for this method

to implement. One potential use of machine learning and image processing is the detection of plant diseases. In the past, plant disease specialists would use chemical methods or visual examination of leaves to identify illnesses. When dealing with large-scale operations, it may be expensive to employ big teams of botanists and to constantly monitor the facility. Under these circumstances, Machine learning and Deep Learning systems are necessary [13]. Decreasing the reliance on manual diagnosis and realizing higher levels of agricultural production, potential diseases' categorizations might be identified using signs on crop leaves quickly and for a low price. But to get more precise results it is better to examine a large set of image metrics or features. Findings are more trustworthy and dependable since a variety of criteria were used to compare various difficulties. This research uses a variety of ML and DL algorithms that were trained on photos of leaves in order to identify plant diseases. There are various ways in which you may classify leaves and these are through color, any injury it may have, among others.

LITERATURE REVIEW

Xuewei Suna proposed a new Convolutional Neural Network model for multi-categories crop disease Image recognition in his study of 2022. These components were added into the model: neural architecture search, focal loss function, attention mechanism, moving flip bottleneck convolution. While employing the proposed NPDD dataset, the study provided a diagnosis for 10 diseases that affect five types of crops with the highest level of accuracy [1].

Using Support Vector Machine, CNN, and K-Nearest Neighbour as the ML algorithms, a system for disease diagnosis in tomatoes was suggested by Sunil S. Harakannanavar et al. (2022). The current method of diagnosing the leaf illnesses to the tomato plants entails using the machine learning techniques mixed with image processing along with exact algorithms. [2] [12].

Real-time identification of agricultural diseases using Nvidia Jetson TX1: Ruchi Gajjar et al. (2021) developed deep convolutional neural network (CNN) architecture in order to identify agricultural diseases having a single-shot detector. To ensure that both the leaf identification and disease grouping models were robust, and were trained on images extracted from the PlantVillage data sets as well as images obtained by the author. High degree of illness categorization accuracy was achieved by the method [3].

Lili Li et al. (2021) detailed these features and limitations of deep learning technology for diagnosing crop diseases in agriculture. Published here are the most current findings from the field of deep learning technology management as it pertains to the identification of leaf diseases in agricultural settings. Taking deep learning algorithms and the modern imaging techniques into consideration, the authors discuss the state of art of crop disease identification from the leaf sample and the challenges it underwent. [4].

A CNN based approach designed by Mohit A. et al. (2020) contains three layers from each convolutional layer and three max-pooling layers. It was the arranged setup to plan a CNN that would have three Convolutional layers and three Max pooling layers. The experimental study based on data of Plant Village, specifically the tomato leaves, and every layer of the CNN had a different number of filters. Nine type of sickness categories were grouped together in the set as well as one photo category for healthy leaves. To ensure that the problem of class imbalance does not affect each class of the photographs, data augmentation

processes were used and standardized the number that belonged to each class of the data samples. Specifically looking at a study of ten different disorders the model was 91.2% accurate in the selection of one of the healthy types [5].

Hilman F. Pardede et al. (2020) on the depth CNN network were able to achieve enhanced results by incorporating double residual networks into a deep CNN framework than the referenced DCNN networks. The new idea in architecture discussed this paper is Compact Networks (ComNet), the designing for deep convolutional neural networks (DCNNs). Using two concatenated residual networks, we solve the issue of evaporating slopes which is inborn in profound organizations. By doing so, the network may be trained better and improved form is achieved eliminating the declining gradient problem. The research implemented the dataset and a set of photos belonging to six classes of tea leaves to evaluate and compare ComNet with six other CNN configurations. The contents of the tea leaf dataset remember five of the most well-known sicknesses for Indonesia and recommendations for healthy living. Author used data samples of tea classified into six categories to test their approach's performance [6].

Vibhor Kumar Vishnoi et al. (2020) concentrated on an automated system for agricultural disease diagnosis based on computer vision and soft computing. They employed several phases, feature extraction approaches, and crop kinds. Scientific work done on the identification of crop diseases using photo of the affected leaves has been done carried out by scientists who have utilized utilization of PC vision and delicate figuring. In this article, first, the authors of the researches and works reviewed will present their views on their research, useful for further consideration and analysis of the advantages and disadvantages of the work done. Besides reviewing the research environment for a various stage of the plant disease detection system, it provides an insight into common plant diseases [7].

By applying k-mean clustering with the help of GLCM characteristics, Anjna et al., (2020) developed an algorithm for identification and classification of capsicum infections. The method discussed many fungal and bacterial diseases which affect capsicum plants. To analyze the variation in bacterial or fungal infection types of the capsicum leaves, the GLCM structures were obtained from the infected region only. These variables were used to categorize the disorders using support vector machines (SVMs) as the classifier. Many classifiers were used in both training and

classification including Tree, Linear Discriminant, K-NN, SVM. That being the case, this application's outcome was most optimally achieved by two of these classifiers: KNN and SVM. For testing the method, 62 images of capsicum plants, both healthy and diseased, along with their leaves, were chosen as data samples. When classifying between the healthy and the sick photos, a high accuracy rate of 91% was obtained when using SVM [8].

These observations indicate the possibility of achieving high accuracy and real-time results as the foundations for the breakthroughs in the plant disease diagnosis using the ML and DL alternatives. The general objective is to advance the knowledge in and promote the increased functionality, effectiveness and applicability of plant disease detection models; this will be realized while considering crop, region, and related agricultural players' and customers' needs.

METHODOLOGY

The primary reason for the proposed framework is to identify diseased leaves by examining their shape, color, and texture. Data extraction from leaves, data samples divided into training and testing datasets, application of DL algorithms, and classification of leaf images as normal or sick make up the proposed approach. A DL method Applying CNN, plant leaves may be categorized as healthy or sick. If a plant leaf is infected, CNN can determine the kind of illness and the plant's overall health. There is a vast array of issues that diseases may bring about in plants. Environmental disorders include the most common diseases, which include infections caused by bacteria, virus, and fungi in addition to other variables including temperature, nutritional excess or loss, humidity, and light. A treatment for a certain disease has been proposed, which promotes the growth of healthy plants and enhances their harvest.

As a result of disease identification, diseased leaves may change shape, color, or texture, among other visible changes. There is a lot of trouble seeing the variations since they all follow the same patterns. The prompt identification and treatment might potentially prevent significant harm to the whole plant.

Dataset

The 18,000 images of both healthy and sick leaves in the experimental dataset are categorized into, which are divided into 14 groups based on species and condition. Prior to optimization and model predictions, the image is

downsized to 256x256pixels. The procedure for processing the photos is as follows [9].

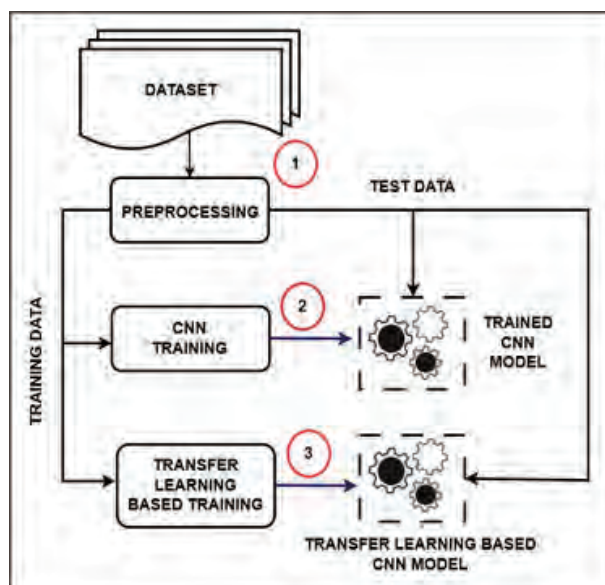


Fig. 1: Proposed Methodology Architecture

- Various procedures and preparations needs to be conducted before inputting data. Image augmentation is an effective image classifier.
- Supervised learning is used to create a model that works well with invisible data. Two distinct datasets are created, one for training and another for testing. There is no substitute other than a random sampling. Two datasets, one for preparing and one for testing, have been extracted from the Kaggle dataset. Data is divided in half using the train test split function. The ratio for the exam is 80:20.
- Using dataset the CNN model is trained to detect leaf diseases. A variety of plant kinds are detailed here:
 1. Tomato
 2. Corn
 3. Grapes

CNN Architecture

Two primary parts make up a CNN architecture: ReLUs and feature extraction. Convolutional neural networks (CNNs) rely on ReLUs for their activation functions, convolutional layers, and pooling layers. The distinguishing features of every convolutional neural network (CNN) architecture are the quantity and arrangement of layers, as well as the existence of additional processing units. A convolutional

layer finds and labels distinct Image features during feature extraction. The result of the convolutional layer is then conveyed off a completely related layer, which, using the data assembled from before layers makes a class prediction for the Image.

1) Layer for Convolution: In convolutional neural network (CNN) the convolutional layer is the most reliable layer. The learning filter, also known as a kernel, has tiny receptive fields that take in all of the input noise. Following the convergence of each filter throughout the height and breadth of the input volume, an activation map in two dimensions is created for that filter in the forward pass. As a result, when the network identifies a certain feature at a particular location in the input data, it learns active filters.

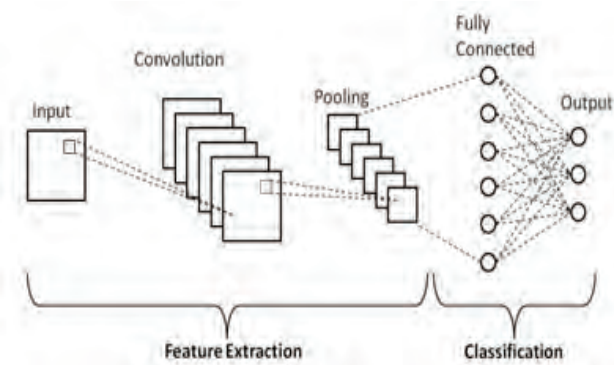


Fig. 2: CNN Architecture

2) Max Pooling layer: Another thought behind CNN is pooling, which is a sort of non-straight down-inspecting. The maximum pooling method is by far the most common, however there are many other nonlinear functions that may be used to generate pooling. The information Image is separated into square shapes, and the most significant value in each region is returned.

3) Fully connected layer: After applying convolutional and max pooling layers, the last characterization utilizes layers that are totally consolidated. A completely associated FC layer in a non-convolutional artificial neural network will have connections to all activations in the layer below it. It is possible to determine their activations by use of a relative change that utilizes framework duplication along with a predisposition offset. The author created a web program that first analyzes plant leaf images by resizing them to 256x256 pixels. Once it is done, it normalizes the variety and then turns the artwork into an array. Since the learnt model can only accept an array of integers as input, the normalized collection spans from 0 to 1.

MobileNet Architecture

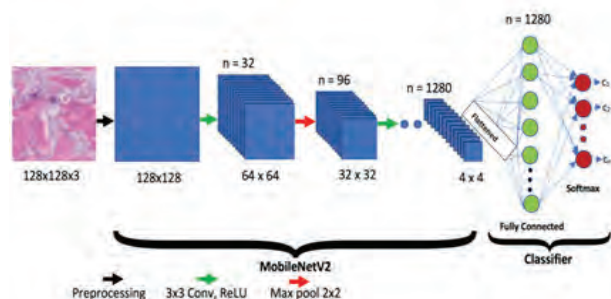


Fig. 3: MobileNet Architecture

1) Model Architecture: An often-used model for Image categorization, the MobileNet model used in this research is built on top of the pre-trained MobilenetV2 architecture. The dataset of images of plant leaves is used to fine-tune the model's last layer. Following convolutional neural networks and maximum pooling layers, the model included several fully connected layers.

2) Training: Training the last layer of the MobilenetV2 model with the set of images of plant leaves allowed for some customization. Author utilized the Adam optimization method and the categories cross-Entropy loss coefficient to fine-tune this model. The fine-tuning might last up to twenty-five epochs.

3) Evaluation: Author used testing information and the presentation boundaries framed in the technique to evaluate the MobilenetV2 system's efficiency.

Transfer Learning

When working with MobileNetV2, one common strategy is transfer learning, this allows making use of previously trained models on massive datasets. Faster training and better use of the source dataset information are both achieved by starting the model using pre-trained weights. Transfer learning changes final layer by allowing fine tuning for greater accuracy.

Algorithm

Step 1: Removal of the background or image pre-processing.

Step-2: Feature extraction is the method used to extract characteristics from photographs.

Step -3: Assess and map the region that has been impacted.

Step-4: Data samples were gathered and analyzed based on the premise that.

Step-5: Extraction of Training Data: In random fashion the Images in the dataset are divided.80 percent is used for testing of images.

Step-6: Testing Data Extraction: The dataset images are randomly split up. Of the split data, 20 percent is employed to test the proposed model.

Step-7: Metrics that measure the performance include accuracy.

Step-8: Classification: characteristics such as Healthy, Early Blight, and Late Blight may be present in the test results. These characteristics are used for predicting the plant's health and categorization purposes.

Step-9: Show final output result on the screen as diseased organ/tissue or healthy organ/tissue.

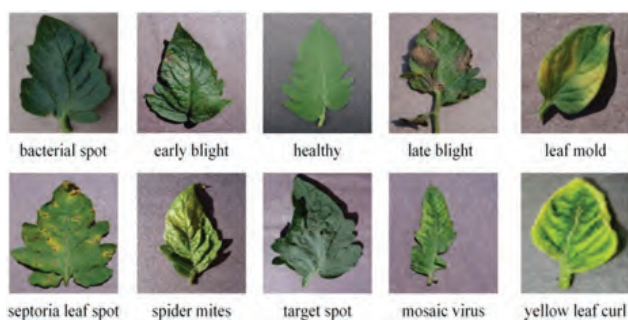


Fig. 4: Images of Tomato Plant Leaves Showing Their Current State of Health

RESULTS AND DISCUSSION

The activities that have been carried out to detect illnesses in plant leaves have their findings summarized. Algorithms for measuring convolutional neural network performance:



Fig. 5: Train and validation accuracy obtained through CNN Model

The trained model achieves an accuracy of 98.23% after 25 epochs. In contrast, plant leaf Images from unseen data

attained an accuracy of 98.23%. The model that has been prepared performs splendidly on the covered plant leaf photos, and it can precisely foresee both the leaf and the sickness with a precision of around 98%.

After training, the model successfully predicted the outcomes of 14 distinct class label tests with plant leaves chosen at random images from the dataset. This demonstrates how well a prepared model can perform on unseen images of plant leaves.

Precision of Preparing and Testing Models: As the quantity of ages expands, the preparation and testing exactness are practically in a similar region, as displayed in Figure 5. That the prepared model has respectable performance metrics is shown.



Fig. 6: Resulted Output

Below is the information that is used to illustrate the expected output:

1. Plant Name
2. Health status
3. Disease Name

An example of the expected results from the plant disease detection system is shown in Figure 6, which includes the name of the plant, the current health condition, and the name of the disease.

The outcome of the research that used deep learning to detect plant diseases are presented here by the author. Three separate models—VGG16, ResNet, and MobileNet—are used to train and assess the system on the same dataset. The results were compared. For this comparison, The Following performance matrices are used: F1 score, recall, accuracy, and precision. F1 score, accuracy, precision, and recall are the most chosen alternatives. A number of

techniques are used to determine a model's accuracy in data instance classification. [11].

1) Accuracy: Here, we quantify the accuracy of a model by dividing the number of accurate predictions by the total number of predictions. Well, here's the formula:

Accuracy = (True Positives + True Negatives) / Total Observations

2) Precision: The ratio of a prediction system's total number of accurate forecasts is known as coverage ratio. The formula is:

Precision = True Positives / (True Positives + False Positives)

3) Recall: Recall is the percentage of correct prediction in relation to the total amount of correct observation made. The computation is done as:

Recall = True Positives / (True Positives + False Negatives)

4) F1 Score: This metric is the average of the two variables, unlike the simple mean where the two are measured. Since they are made equal, it affords a sound overview of a model's overall performance for comparison. F1 Score = $2 * (\text{Precision} * \text{Recall}) / (\text{Precision} + \text{Recall})$ is the formula which is used to calculate it.

The study's findings are compiled in Table 1. While carrying out the study, the three deep learning models are evaluated on a single classification task, and- includes ResNet, VGG16 and MobileNet. Four standard performance indicators are used to assess the models:

Four metrics: F1 Score, Accuracy, Precision, and Recall.

Table 1. Comparison

Model	Accuracy	Precision	Recall	F1-Score
VGG16	0.86	0.88	0.87	0.87
RESNET	0.93	0.93	0.93	0.93
MOBILENET	0.98	0.98	0.98	0.98

The aggregate percentage of cases that are properly categorized is called accuracy. According to the accuracy, among the three CNN models the highest accuracy is of MobileNet (0.98), followed by VGG16 (0.86), and ResNet (0.93). Given the results obtained in the evaluation metrics, all three models can operate with high accuracy in the test dataset.

These discoveries into plant leaf diseases present practical applications in relation to this particular research study.

One can design systems that recognize plant diseases from images of the plant's leaves with deep learning algorithms. Some of these technologies may enhance the productivity and quality of agriculture, and may also decrease the role of diagnosis and inspection of human beings. Most importantly, especially to farmers in remote areas, forming mobile app may significantly enhance the levels of mobility and ease. It may be asserted that expanding on the results of this study may greatly enhance practical applications in this sector.

CONCLUSION

More specifically, the system of plant disease detection technique will use deep learning to offer precise disease diagnosis and classification. The identified techniques incorporate transfer learning and convolutional neural network (CNN), and the proportion of correct diagnosis of known illnesses on crop leaves is 98.23%. This research offers a better follow-up approach of the previous systems and exercises as it is far accurate than the previous systems and can be more easily used by farmers. The technology has potential to boost agricultural yields and processes farming operations that in turn has potential to increase per capital income especially due to health risks and yields checking facilities. For its training phase the model takes a total of 25 iterations.

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Design and Development of an Efficient Internship Management System, A Review

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ABSTRACT

The Internship Management System (IMS) is designed to streamline the end-to-end processes involved in managing internship programs, from intern applications to evaluations and completion certifications. Traditionally, internship management has been a manual and fragmented process, resulting in inefficiencies, communication gaps, and delays in onboarding, project assignments, and intern evaluations. This paper presents a web-based IMS developed using the Django framework, which integrates key stakeholders including interns, HR personnel, hiring managers, and other relevant stakeholders in a centralized platform. The system automates the application and approval process, allows HR to assign interns to specific projects managed by hiring managers, and facilitates stakeholder tracking of intern progress. Key functionalities include project assignment, intern evaluation, and automated notifications, which enhance communication and reduce administrative burden. The IMS is built on a scalable architecture that supports secure data handling and role-based access, ensuring that data privacy and integrity are maintained. Preliminary evaluations indicate that the IMS improves operational efficiency and intern satisfaction by providing a structured and transparent process flow. This research discusses the design, implementation, and potential impact of the IMS on internship program management, offering insights into its scalability and adaptability for future enhancements.

INTRODUCTION

The Internship programs are crucial for providing students with practical experience, but managing these programs can be challenging for organizations due to the high volume of applications and coordination among multiple departments. Traditional methods often rely on manual processes, resulting in delays, inefficiencies, and lack of transparency, which can impact both intern and organizational satisfaction.

The Internship Management System (IMS) addresses these challenges by providing a centralized, web-based solution built on the Django framework. Designed to streamline intern applications, project assignments, evaluations, and completion certifications, the IMS integrates key stakeholders—HR, hiring managers, and interns—on a single platform. Key functionalities include automated

workflows, project tracking, and role-based access, allowing each user to interact with data specific to their responsibilities.

This paper outlines the design, implementation, and impact of the IMS, demonstrating its ability to optimize internship management processes. By automating key tasks and improving communication, the IMS not only enhances operational efficiency but also improves the overall intern experience.

PROPOSED APPROACH

The development of the Internship Management System (IMS) follows a structured, stage-wise approach, each phase building on the last to create a comprehensive, user-friendly platform.

A. In Stage 1: Requirement Analysis, the objective is to

gather and document all functional and non-functional requirements from key stakeholders, including HR, hiring managers, and interns. This involves conducting interviews, workshops, and surveys to define use cases and refine system requirements, resulting in a detailed Requirements Specification Document that outlines essential functionalities, user roles, and data flow.

- B. Stage 2: System Design focuses on translating these requirements into a structured system blueprint. This involves designing the database schema for storing data on interns, projects, and evaluations, as well as creating system architecture diagrams, class diagrams, and data flow diagrams (DFDs). Additionally, user interfaces are designed for each role, ensuring easy navigation and secure role-based access to features. The output of this stage is a comprehensive design document, including UML diagrams and wireframes.
- C. In Stage 3: Development, the actual system is built using the Django framework, based on the specifications from the design phase. Core modules are developed to support user authentication, internship application processing, project assignment, and evaluation functions. Automated email notifications are integrated to keep users informed of key updates, while role-based access control ensures that permissions align with each user's responsibilities. This stage results in a functional prototype of the IMS with a backend that supports all primary features.
- D. Stage 4: Testing is essential to ensure the system's reliability and usability. Unit testing is conducted on individual modules, followed by integration and system testing to validate end-to-end workflows. Feedback from potential users is incorporated to address usability issues and enhance functionality. This stage ensures that the IMS is bug-free and stable, ready for deployment.
- E. Finally, in Stage 5: Deployment and Maintenance, the IMS is deployed on a secure server, with user training sessions provided to facilitate adoption. Ongoing maintenance includes monitoring performance, addressing user feedback, and implementing updates for continuous improvement. This phase results in an operational IMS that supports efficient internship management, with a plan for long-term support and enhancement.

- F. This stage-wise approach ensures a systematic and reliable path to developing an IMS that meets user needs while optimizing internship management processes.

PROCESS FLOW

TECHNICAL CONCEPT

User Authentication and Authorization

The IMS employs Django's built-in authentication system to manage user login and role-based access. Users (interns, HR, hiring managers) are assigned specific roles, which determine their access rights within the system.

Role-based access control (RBAC) is implemented to restrict certain actions and data views, ensuring that users interact only with data relevant to their role.

Data Modeling and Database Design

Using Django's Object-Relational Mapping (ORM), the database schema is defined to support entities like users, projects, evaluations, and clearance processes. Each entity is modeled as a class in Django, and relationships (one-to-many, many-to-many) between these classes define how data is stored and retrieved.

Database normalization techniques are applied to reduce redundancy and ensure efficient data storage.

Application Processing and Workflow Management

For application management, a state machine design pattern is implemented to handle different application statuses, such as "Applied," "Under Review," "Approved," or "Rejected."

Each stage in the intern application and onboarding process is represented as a distinct workflow. Django signals or Celery (for asynchronous processing) can be used to automate transitions between workflow stages.

Automated Email Notifications

Email notifications are triggered at key workflow events, such as approval of an internship, project assignment, or clearance completion.

The Django email framework is used for this purpose, enabling automated, template-based email sending to relevant stakeholders.

File Handling and Document Generation

Intern resumes and certificates are uploaded and stored

using Django's file handling capabilities. Generated documents, such as certificates or clearance forms, are handled with libraries like xhtml2pdf for creating PDFs dynamically.

To ensure data security, stored files are encrypted, and access to documents is restricted based on user permissions.

Logging and Audit Trail

For tracking and accountability, a logging system is integrated within the IMS to capture critical actions (e.g., project assignments, evaluations, intern approvals).

Django's logging framework allows detailed tracking of system actions, providing an audit trail for HR and administrators.

Front-End and User Interface (UI) Design

The front-end is designed with HTML, CSS, JavaScript, and Django templates to ensure responsive and role-specific interfaces.

Forms and input validation are handled on both client and server sides to enhance data integrity and user experience.

RESTful API for System Integration

A RESTful API layer is provided to allow other internal systems to access IMS data (e.g., intern data or project status). This API is built using Django REST Framework (DRF), which supports authentication and authorization for secure data sharing.

Data Security and Privacy

The system implements HTTPS for secure data transmission, and sensitive information like passwords and personal intern data is encrypted in storage.

Django's CSRF and SQL injection protections are applied to secure forms and prevent unauthorized access.

Testing and Continuous Integration

Unit testing and integration testing are conducted using Django's built-in testing framework to validate individual functions and system workflows.

HARDWARE/SOFTWARE REQUIREMENTS

Hardware Requirements

Server Requirements

- Processor: Quad-core processor, 3.0 GHz or higher (e.g., Intel Xeon, AMD Ryzen).
- RAM: Minimum 8 GB (16 GB recommended for optimal performance).

- Storage: SSD with at least 256 GB for the operating system and application, and an additional 500 GB for database storage and file uploads.

- Network: High-speed internet connection with a minimum 100 Mbps bandwidth for optimal user accessibility.

Client Requirements (Users accessing IMS from personal devices)

- Processor: Dual-core processor, 2.0 GHz or higher.
- RAM: Minimum 4 GB.
- Storage: Minimum 2 GB free space.
- Display: 1024 x 768 screen resolution or higher.
- Network: Stable internet connection, minimum 5 Mbps.

Software Requirements

Server-Side Software

- Operating System: Ubuntu Server 20.04 LTS or Windows Server 2019.
- Web Server: Nginx or Apache for handling HTTP requests.
- Framework: Django 3.x or higher (Python 3.8+).
- Database: SQLite for reliable data management and scalability.
- APIs and Libraries: Django REST Framework for API management, Celery for task scheduling (optional).
- Security: SSL certificates for secure HTTPS communication.

Client-Side Software

- Browser: Compatible with modern web browsers like Chrome, Firefox, Safari, or Edge.
- JavaScript and CSS Libraries: React or Bootstrap for responsive, interactive front-end design.

Development and Testing Tools

- IDE: PyCharm, Visual Studio Code, or another Python-compatible IDE.
- Version Control: Git for source code management and collaboration.
- Testing Tools: Django's built-in testing framework and Postman for API testing.

Additional Software Requirements

- i. Document Processing: xhtml2pdf for certificate and report generation.
- ii. Automated Email: Integration with SMTP services or third-party providers like SendGrid.
- iii. Monitoring: Tools like Prometheus and Grafana (optional) for server performance monitoring.

PROJECT OBJECTIVES

- A. To Streamline Internship Management: Develop a centralized system to automate and manage the complete internship lifecycle, from applications to evaluations, reducing manual effort and improving efficiency.
- B. To Enhance Communication and Collaboration: Facilitate effective communication among HR, hiring managers, and interns with automated notifications, role-specific dashboards, and project updates.
- C. To Ensure Data Security and Role-Based Access: Implement role-based access controls to restrict data visibility and actions according to user roles, ensuring data privacy and secure handling of intern information.
- D. To Provide Real-Time Tracking and Reporting: Enable HR and managers to track intern progress and generate reports on performance, application status, and project assignments to support data-driven decision-making.
- E. To Improve Intern Onboarding and Evaluation: Streamline onboarding and create structured, criteria-based evaluation processes to provide interns with clear goals and feedback, enhancing their overall experience.
- F. To Automate Key Administrative Tasks: Automate application approvals, project assignments, and certification issuance to reduce administrative burden and improve the efficiency of HR operations.

PROJECT MODULES

- A. User Management: Manages user registration, authentication, and role-based access for interns, HR, and hiring managers, ensuring secure login and data privacy.
- B. Application Processing: Allows interns to submit applications and resumes, while HR and hiring managers can review, approve, or reject applications based on eligibility criteria

- C. Project Assignment: Enables HR to assign interns to specific projects created by hiring managers, facilitating structured assignments and tracking of project allocations.
- D. Intern Evaluation and Feedback: Provides tools for hiring managers to evaluate interns based on defined criteria and give feedback, supporting structured performance reviews and skills assessments.
- E. Document Management: Handles secure storage and access for intern-related documents, such as resumes, evaluation forms, and certificates, ensuring organized and easy retrieval.
- F. Automated Notifications and Communication: Sends automated email notifications to interns, HR, and hiring managers for updates such as project assignments, evaluation reminders, and certification issuance.
- G. Report Generation and Analytics: Generates reports on internship status, project progress, and performance metrics, allowing HR to analyze data and make informed decisions.
- H. Clearance and Certification: Automates the final clearance process and generates internship completion certificates for qualified interns, streamlining the exit process.

SYSTEM ARCHITECTURE

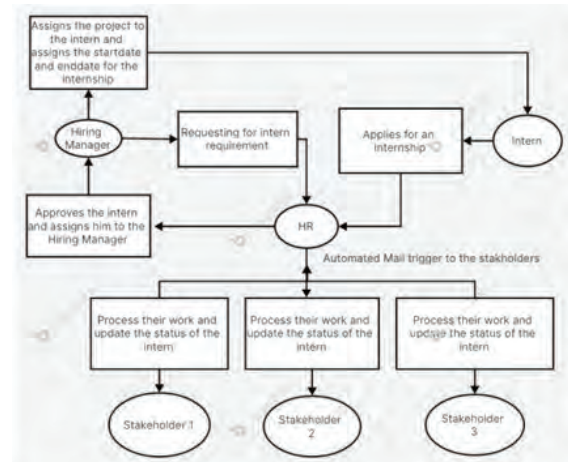


Fig. 1. System Architecture

FUTURE SCOPE

The Internship Management System, as developed, has significant potential for future expansion and enhancement. With further development, it could incorporate additional functionalities that improve usability, accessibility, and

overall effectiveness. Some potential areas for future enhancement include:

- A. **Integration of Task Management and Reporting Features:** Expanding the system to allow interns to track their tasks and generate reports would provide a comprehensive overview of each internship experience and enable better performance assessment.
- B. **Real-Time Notifications and Alerts:** Implementing a notification system for updates on internship status, application feedback, or document submission reminders could improve communication and engagement.
- C. **Enhanced Security through Role-Based Access Control:** As the system grows, implementing role-based access control would ensure secure, structured access for different user types, such as interns, mentors, and administrators.
- D. **Advanced Analytics and Reporting:** Adding analytical tools would allow organizations to track intern performance trends and program effectiveness, facilitating data-driven decision-making for future program improvements.
- E. **AI-Driven Recommendations and Matching:** Integrating artificial intelligence could enhance the intern-recruiter matching process, providing tailored internship recommendations based on the intern's skills, interests, and goals.
- F. **Scalability to Support More Technologies and Larger User Bases:** Currently built using Django, SQLite, HTML5, CSS3, and JavaScript, the system can be expanded to incorporate more robust databases and frontend frameworks, improving scalability and performance.
- G. **Mobile Compatibility and Accessibility:** Optimizing the system for mobile devices and enhancing accessibility for a diverse range of users would broaden its usability and impact.

PROJECT GOAL

The goal of the Internship Management System project is to create a centralized, efficient platform that simplifies the internship management process for both interns and administrators. By digitizing workflows, the system aims to streamline application handling, intern tracking, and document management, thereby reducing manual effort and minimizing administrative burdens. Built with Django,

SQLite, HTML5, CSS3, and JavaScript, the project focuses on providing an intuitive and accessible user experience while ensuring reliability and data integrity. The ultimate objective is to enhance the internship experience by fostering transparency, organization, and effective communication between interns and program administrators.

CONCLUSION

The Internship Management System project aims to streamline and simplify the internship management process by providing a structured, user-friendly platform. Built using Django, SQLite, and core web technologies, the system effectively manages essential internship workflows, contributing to a more organized and transparent experience for interns and organizations alike. By reducing manual processes and centralizing information, it provides an efficient solution to many challenges currently faced in internship management.

Though still in its foundational form, the system sets a solid base for future growth, with potential for adding advanced features such as real-time notifications, task tracking, and analytics capabilities. Through continuous improvement and potential integration of additional technologies, this project has the potential to serve as a comprehensive, scalable solution that meets the evolving needs of internship programs across diverse industries.

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Candidate Selection Using Online Job Portal

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ABSTRACT

This system aims to create a chatbot-driven platform that simplifies the job search and resume creation process for users. By leveraging artificial intelligence, Natural Language Processing (NLP), and resume analytics, the system offers a user-friendly and interactive experience for job seekers. Key features include a registration and login system that provides personalized access to users. The chatbot allows users to ask job-related questions, offering real-time assistance on available job opportunities, interview preparation tips, and insights specific to various industries. Additionally, the platform streamlines resume generation by enabling users to enter their basic information, which the system then transforms into a polished, professional resume that meets industry standards. Overall, this platform is designed to empower job seekers by providing them with the tools and resources they need to succeed in their career pursuits.

KEYWORDS : *Resume Creation, Artificial Intelligence, NLP, Job Search, Real time assistance.*

INTRODUCTION

Job seekers frequently encounter several difficulties in the competitive job market of today, ranging from creating a strong CV to negotiating the intricacies of applications and interviews. For people who do not have the required tools or direction, the procedure might be extremely daunting. We are creating a chatbot-powered platform that will transform how people approach resume writing and job searching to address these issues. This cutting-edge technology gives consumers an intuitive and engaging experience by fusing the capabilities of artificial intelligence and Natural Language Processing (NLP). By utilizing these technologies, the system ensures that users may produce professional documents that adhere to industry standards while also providing job seekers with individualized guidance and streamlining the resume generating process.

In today's fast-paced digital era, the job market has become increasingly competitive and complex, requiring job

seekers to stay ahead by leveraging innovative tools and strategies. This platform encourages users to take control of their career paths with features including real-time job-related support, interview preparation suggestions, and industry information. By creating an environment that is easy to use, we hope to make the job search process less intimidating and more effective, ultimately assisting people in finding the opportunities that best suit their goals and skill set.

For many job seekers, particularly those new to the workforce or transitioning between industries, the lack of tailored guidance and accessible tools can make the process daunting and discouraging. The rapid growth of digital job platforms has provided more opportunities but has also introduced complexities like sifting through vast amounts of data and optimizing applications to stand out in the crowd.

The system emphasizes user-centric the design by prioritizing accessibility, ease of use, and personalization,

ensuring that individuals from diverse backgrounds can benefit from its capabilities.

By empowering users with actionable insights and streamlined tools, this platform aims to reduce the stress associated with job searching and enhance the overall success rate of applicants in securing their desired roles. This initiative represents a significant step forward in using technology to bridge the gap between job seekers and the opportunities they aspire to achieve. By fostering a user-centric and intuitive environment, this platform aims to reduce the stress associated with job hunting, streamline the application process, and empower individuals to achieve their career goals efficiently.

LITERATURE REVIEW

In 2024, Amol Halyankar suggested “College Enquiry For Student using AI ChatBot” system which is used for college inquiries by using artificial intelligence & natural language processing algorithm to answer students’ questions related to examination, admission, academics and more through a user friendly interface. The project not only improves user engagement by replacing static FAQ pages with interactive responses but also reduces the workload on administrative staff by automating routine queries.

In 2024, author introduced “Using Machine Learning to Predict Student Success in Undergraduate Engineering Programs”. This system explores the application of machine learning techniques to predict engineering student success by analyzing academic performance in core math, physics, and engineering courses. This innovative system provides actionable insights for academic administrators and educators, enabling data-driven decision-making to improve curriculum design and student support services.

In 2024, Sameer Gupta introduced “A Comparative Analysis of NLP Algorithms for College Chatbots. This paper presents a comparative study of different NLP algorithms in the context of college chatbots, evaluating their performance based on query response accuracy and user satisfaction. The study concludes that selecting the right NLP algorithm for a college chatbot is crucial for maximizing its effectiveness in delivering accurate information and maintaining high levels of user satisfaction.

In 2024, the author investigates job seekers’ perceptions of recruitment through job portals, emphasizing the importance of usability, trustworthiness of listings, and job match relevance. A realistic survey on candidate selection could include questions about user experience with job

portals, perceived effectiveness of job listings, and the level of trust in the platform. Additionally, it could assess how well job matches align with candidates’ skills and preferences, providing valuable insights for improving the selection process in online recruitment.

In 2023, John Doe introduced “AI-Driven Student Assistance System for University Services”. This chatbot system provides AI-driven assistance to university students by offering information on admissions, schedules, and academic support through natural language processing. This AI-driven assistant aims to reduce the workload on administrative staff while enhancing the student experience by providing timely, accurate, and easily accessible information. By streamlining university services through a conversational interface, the system fosters a more efficient and supportive academic environment.

In 2023, Priya Sharma introduced “Development of a College Chatbot Using Machine Learning”. This research presents a chatbot leveraging machine learning algorithms to handle student inquiries about courses, admissions, and general college information, aiming to improve user engagement and response accuracy. The research highlights the chatbot’s ability to reduce the workload on administrative staff and improve the overall efficiency of student services. By automating routine inquiries and offering 24/7 availability, the chatbot enhances the student experience, making it an indispensable.

In 2023, “, Ramesh K suggested “Chatbot for College Admission Enquiry Using NLP and Machine Learning” This chatbot system is developed to assist prospective students in college admission queries. It uses NLP and machine learning techniques to provide accurate, real-time responses, improving user engagement and streamlining the admission process. The chatbot engages prospective students by providing helpful, context-aware responses. With features such as automated reminders for application deadlines, document submission, and interview schedules, the system helps students stay on track throughout the admission process.

In 2022, Emily Chen and Michael Brown suggested

“Improving Student Engagement with AI Chatbots in Higher Education”, This research examines the use of AI chatbots to enhance student engagement, showing that chatbots effectively handle FAQs and provide immediate responses, improving user experience. This research concludes that integrating AI chatbots in higher education institutions not only improves operational efficiency but also significantly enhances the student experience, making information more accessible, timely, and personalized.

In 2022, Sneha Patil and Rajesh Sharma suggested “AI-Based Virtual Assistant for Student Services in Higher Education”. The system developed a virtual assistant using AI to facilitate various student services in higher education, such as course information, scheduling, and event updates, using a conversational interface. The AI-based virtual assistant not only saves time for students and administrative staff but also ensures that students have seamless, timely access to critical information and services.

In 2022, Rahul Verma & Neha Singh suggested “College Enquiry Chatbot Using RNN and Attention Mechanisms”. This system explores the use of Recurrent Neural Networks (RNN) and attention mechanisms in building an inquiry chatbot to improve understanding and response to complex student questions. This approach aims to improve the user experience by delivering more accurate, context-aware, and personalized responses to students.

In 2021, Ashok Kumar & Sunita Patel Suggested “An Intelligent Academic Advisor Using NLP Techniques” system. This system is used as an academic advising chatbot that uses NLP techniques to interpret student queries, providing tailored advice on course selection and career paths. Furthermore, by integrating machine learning, the system refines its responses over time, adapting to individual student needs and feedback.

METHODOLOGY

The methodology for this research involves developing a chatbot-driven job search and resume creation platform by analyzing user needs through surveys, interviews, and literature reviews. The system is designed with key components, including a chatbot for job recommendations, a resume generation module, and a secure database for managing user information. The chatbot interacts with users to provide job-related guidance, interview preparation tips, and resume formatting suggestions. The resume module helps users generate professional resumes based on industry standards. The job recommendation system matches candidates with relevant job opportunities based on their skills and preferences. The platform underwent rigorous testing, including unit, integration, and user testing, to ensure accuracy, efficiency, and a seamless user experience. Risk assessments were conducted to address potential biases in job recommendations, data security concerns, and chatbot misinterpretation. Continuous refinement was carried out based on user feedback and performance analysis to enhance system effectiveness and improve job-matching efficiency.

The diagram represents the organized flow of how a job recommendation system and resume analysis with a chatbot interface works. Everything begins from the User, who has to either Register or Login into the system in order to get started. After authentication, the user accesses the system through the Chatbot Interface, enabling interaction and navigation within the system. The bot provides a number of features, such as Resume Generation, in which users can create a resume through templates or guided steps, as well as Resume Upload, which permits users to upload ready-made resumes. The system also conducts a Resume Analysis that determines the most important skills, experiences, and qualifications the submitted resumes possess in relation to existing job profiles. With this, the system provides Job Recommendations aimed at appropriately matching users with available positions. These features are made possible by a central Database that stores users’ login details, resumes, job offers, and other results of analysis for efficient operations and user satisfaction. This organized flow improves the effectiveness of job hunting using an AI-powered resume analysis and job recommendation system.

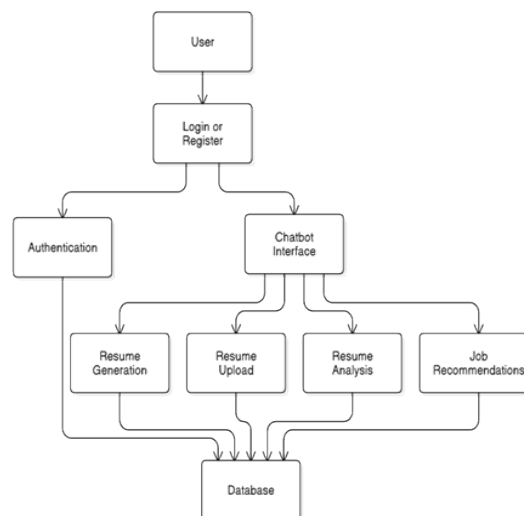


Fig. 1: Block Diagram

CONCLUSIONS

The creation of a chatbot-powered resume and job search portal is a major step forward in helping job searchers in the cutthroat job market of today. This platform seeks to offer individualized, real-time support that tackles the difficulties that people have during their job search process by utilizing artificial intelligence and natural language processing. In addition to making the job application

process easier, the platform boosts users' confidence in their ability to market themselves to potential employers with features including smooth CV generation, personalized job recommendations, and straightforward user interactions. The system will always adapt to the changing needs of job seekers thanks to the incorporation of strong analytics and user feedback systems.

Moving forward, further enhancements can be made by expanding job database integrations, refining natural language processing capabilities, and incorporating real-time labor market trends to provide even more accurate job recommendations. As technology continues to evolve, this platform has the potential to redefine online recruitment by bridging the gap between job seekers and their ideal career opportunities, ultimately contributing to a more efficient and effective hiring ecosystem.

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Intelligent Enterprise Assistant based Geo-Location Tracking System

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ABSTRACT

Accurate attendance management and their instant support have always been a key to success in an organization in the present ever-changing business environment. But due to the manual processes, errors, reduced productivity, and lower employee satisfaction have crept in. An innovative approach based on advanced technologies to provide a single window interface has been defined as a solution to those problems in the proposed system. This application offers geo-location-based attendance tracking joined with an AI-Chatbot for uninterrupted employee experience. Work attendance management is automated while providing intelligent assistance to reduce manual errors, increase efficiency, and enhance employee satisfaction. With the inclusion of document processing abilities, information extraction, and analysis become highly optimized for organizational operations. The proposed system aims to revolutionize attendance support and create a more efficient, smooth, and employee-oriented environment.

KEYWORDS : Employee satisfaction, Geolocation, AI-Chatbot, Intelligent assistance, Document processing.

INTRODUCTION

Modern enterprises are increasingly adopting intelligent systems to automate operations, enhance productivity, and manage their workforce efficiently[1]. These systems leverage AI, NLP, and geo-location services to address challenges like attendance monitoring, real-time employee assistance, and document processing[8]. However, despite advancements, enterprise systems still face limitations that hinder seamless operations, highlighting the need for scalable and adaptable solutions to maintain a competitive edge.

This research focuses on developing an Intelligent Enterprise Assistant with three core capabilities: geo-location-based attendance tracking, an AI-powered chatbot, and intelligent document processing. The geo-location feature automates employee check-in/out using GPS, minimizing errors and preventing attendance tampering. The chatbot, powered by NLP, provides real-

time assistance for HR, IT, and policy-related queries, continuously improving through learning. Intelligent document processing, using OCR and AI-based parsing, streamlines data extraction and management, reducing administrative bottlenecks and enhancing workflow efficiency[13].

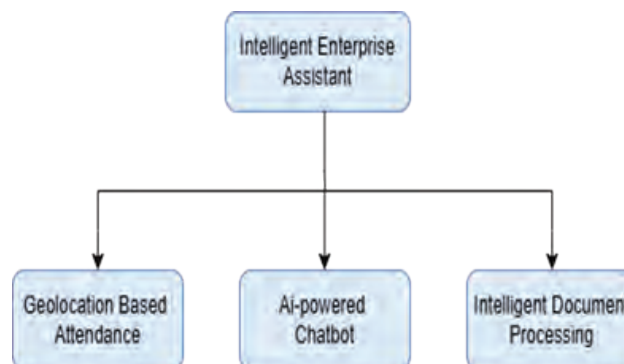


Fig. 1. Intelligent Enterprise Assistance

Although several existing systems already deal with parts of these challenges, they still lack in crucial areas. For example, one of the biggest security threats for location-based attendance systems comes from spoofing; others, AI-chatbots, often deliver disappointing results when posed with domain-specific queries. Document processing too struggles under the weight of many types of diverse and complex data. The Intelligent Enterprise Assistant bridges these gaps through advanced AI algorithms, multi-factor authentication for geo-location, and hybrid models combining machine-learning elements with rule-based ones for chatbot functions. Based on open-source technology, the Intelligent Enterprise Assistant provides a very cost-effective and scalable solution, available for any organization, irrespective of its size. With a robust design emphasizing high data security, accuracy, and versatility, it can revolutionize modern enterprises. This proposal not only fills the current gaps but also lays a strong foundation for future innovation in enterprise management, affecting the very foundation of the way organizations handle their operational business as well as strategic long-term management[2].

LITERATURE REVIEW

The existing methods for enterprise management and operations rely heavily on manual or semiautomated approaches, each with its own set of limitations. Below are some of the commonly used methodologies:

- i. Manual Attendance Monitoring
- ii. Biometric Attendance Systems
- iii. Manual Processing of Documents
- iv. Chat Based Support Systems
- v. Geo-location Systems Without Multi Factor Authentication
- vi. Hybrid Systems

Even though all those mentioned above have managed to serve the purpose in one way or the other, they have not stood against the test of time with respect to the changing emerging needs of businesses today, more specifically as far as scalability, adaptability in real-time, and higher order data integration are concerned. This is precisely what our Intelligent Enterprises Assistant is expected to overcome, using Geo-location technology, AI-driven chatbot, and advanced document processing to showcase improved economy, scalability, and enhanced intelligence

at providing better solutions. Following table 1 shows the summary and limitations of the related work:

Table 1 Summary and limitations of related work

Ref. No.	Summary	Limitations
[1]	Tells about the development, applications, and security issues of RFID technology.	The paper focuses more on general aspects of RFID rather than specific implementations or performance insights.
[2]	Explains the development of a biometric-based attendance management system for reliability and accuracy.	There are not many details about scalability and integration with modern systems.
[3]	Proposes a location-based time and attendance system using mobile devices and GPS technology for accurate tracking.	Dependent on GPS availability and precision; lacks focus on privacy concerns.
[4]	Introduces an automated attendance monitoring system implemented on the Android platform.	Limited platform scope (Android only); does not address cross-platform compatibility.
[5]	Presents a mobile attendance application using geo-fence technology for location-based tracking and management.	Geo-fencing requires precise location data, which may not always be accurate or reliable.
[6]	Proposes an AI-based chatbot for addressing enterprise business problems, showcasing its adaptability in handling queries.	Lacks implementation details specific to attendance or location tracking applications.
[8]	Discusses developments in chatbot technology with the use of NLP to enhance communication and task management.	Limited focus on practical use cases, such as attendance management or location-based tracking systems.
[9]	Explores the integration of chatbots with NLP for the discovery of location and providing support to users through intelligent conversations.	Does not delve into integration with real-time attendance systems or security challenges.
[10]	Geo-location-based attendance management system that increases the accuracy of tracking and system efficiency.	It requires reliable internet connectivity and advanced security measures to prevent location spoofing.

[11]	GPS-based automated attendance system for accurate and efficient monitoring of employee attendance.	Limited testing in environments with poor GPS signal or multi-floor buildings.
[12]	Describes a real-time attendance system with 2-step authentication, which increases security and reliability in attendance management.	Increased complexity and potential usability challenges due to the 2-step authentication process.

METHODOLOGY

Intelligent Enterprise Assistant consolidates all features and tools to serve the purpose of optimizing enterprise workflows with high-end technologies such as Geo-location tracking, AI-driven chat-bot, and cloud infrastructure. It encompasses the automation of essential processes, such as employee attendance tracking, employee support, and document management, thus serving as a scalable and secure solution that facilitates day-to-day operations.

Proposed work has the following key Features and Objectives:

i. Geo-location Based Attendance Tracking

Employees check-in and checkout with GPS-enabled mobile devices to have accurate and real-time attendance logging. Multi-factor authentication further confirms the identity of the user and complements security against manipulation or spoofing [10].

ii. AI-Powered Employee Support Chat-bot

The chat-bot acts as an assistant for HR, IT, and policy related queries. It is trained using natural language processing and adapts changing scenarios[8].

iii. Efficient Document Management

AI-based OCR tools are used to provide great simplification in administration tasks in data extraction, report generation, etc., to gain efficiency in administrative workflows [9]. Doing so causes less difficulty for the administrative team and improves accuracy.

System Architecture Overview

As depicted in Figure 2, the system is organized into three main layers:

1. Client Layer:

Employees interact through a mobile app to log attendance, access the chat-bot, and submit documents. Managers use

a web dashboard to analyze data and generate reports in real time.

2. Application Layer:

The core modules that run attendance tracking, chat-bot capabilities, and document processing seamlessly together, leveraging third-party API's for Geo-location, NLP, and cloud storage.

3. Data Layer:

All the data, including attendance log, chats with the chat-bot, and uploaded documents, are stored in a secure, encrypted cloud database, ensuring compliance with privacy standards.

Advantages Over Traditional System

On the contrary, the Intelligent Enterprise Assistant processes real-time and error-free data unlike the traditional systems of manual attendance or standalone biometric systems. Attendance Tracking Replaces errors and delays in manually logging GPS trails with an automated one. Integrated Support employees have the means to address all types of requests, including attendance updates, IT support, or document submissions, from one interface. The system allows for easy adaptation to growth and sustains reliability and performance for large groups. By consolidating all these features under a single platform, Intelligent Enterprise Assistant provides a novel offering that simplifies the workflow, enhances security, and suits the dynamic needs of present-day enterprises.

SYSTEM DESIGN

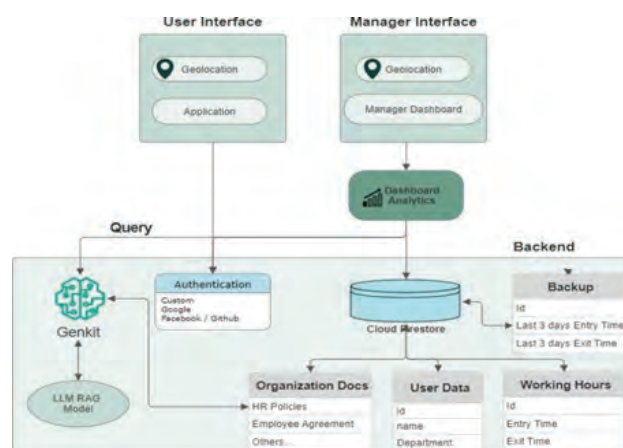


Fig. 2. System Process Flow

The Intelligent Enterprise Assistant is setup as an Android application that has separate interfaces for the employees

and managers. It embodies modern concepts of efficient enterprise management and gives the user experience in seamless integration and unification.

i. User Interface (Relevant Employee Interface)

The Employee Interface is this very Android application that combines Geo-location tracking and an AI-powered chatbot to enable him secure attendance marking and the access of support resources. The Geo- location tracker does employ multi-factor authentication methods to ensure non-allowance for location spoofing or unauthorized access.

This is the relatively simple method by which the employee would be able to see the attendance records with respect to effective entry-as well as emergency exit times. These records would be stored in real-time synchronization from the backend.

The application integrates an AI-driven chatbot powered by the GenKit module. This chatbot uses a Large Language Model (LLM) with Retrieval- Augmented Generation (RAG) to process the employees' queries . It retrieves important information from their backend-stored organizational documents, such as HR policies, employee agreements, etc., as well as FAQs. By providing real-time assistance and understanding the current context of the query, the chatbot is able to reduce manual work in the HR teams' hands. Designed in a user-friendly way, the application will be user-friendly for employees with limited technical expertise.

ii. Manager Interface

Manager Interface is also placed in Android-based applications that equip the managers with advanced tools in workforce management. The Geo-location analytics system makes it possible to track the patterns and trends of employee attendance. This interface features a real-time dashboard with data analytics, allowing managers to detect anomalies in attendance patterns, such as irregular attendance or frequent late arrivals .It also provides managers with applications available directly in the app for review and approval, such as employee requests for leave. As with the Employee Interface, this interface is equipped with multi-factor authentication for secure access. The system sends respective alerts and notifications automatically for attendance irregularities to quicken the response activity for managers.

iii. Back-End Infrastructure

The back-end employs the real-time data management

capacity of Google's Cloud Firestore and geographical verification through Google Maps API to ensure secure handling of critical data . The personal information of users, logs of Geo-location, working hours, and documents of the organization are stored securely in it.

Keeping a backup of attendance logs (entry and exit) for three days and disaster recovery will also ensure reliability in data. Multi-factor authentication is implemented to add layers of security in order to prevent unauthorized access.

Increased security includes multiple methods required for authentication before one gains access to shared network resources. The multiple ways include custom organizational logins, Google, Facebook, and GitHub authentication, thus providing flexibility to the user as per requirement. Additionally, end-to-end encryption secures data transmission.

iv. GenKit AI Module

As an LLM tuned for specific enterprise tasks, it integrates Retrieval-Augmented Generation (RAG) into the architecture to provide a mixture of AI reasoning and real-time document retrieval. Employees and managers receive context-aware, real- time responses to queries based on the latest organizational data. These responses will be modified dynamically by the AI as new data becomes accessible to the system.

v. Data Synchronization and Analytics

This system uses Firestore's real-time database capabilities to join seamlessly the Employee and Manager Interfaces with the back-end. A Dashboard Analytics module processes workforce data before visualizing it through Google Charts or similar libraries to provide a useful insight into workforce patterns and trends. Notifications and alerts are controlled by Firebase Cloud Messaging (FCM) to facilitate instant communication between their employees and their managers.

TECHNICAL FEATURES SUMMARY

The system, built using Flutter/Dart, follows Material Design principles for a seamless Android experience. It utilizes Google Cloud Firestore for secure data storage, including user profiles, geo-location, and working hours, while Firebase Authentication ensures secure access. Google Maps API enables accurate attendance tracking, and Firestore's real-time synchronization, along with Firebase Cloud Messaging (FCM), provides instant updates and alerts.

An AI-powered module, integrated with GenKit, employs Large Language Models (LLMs) and Retrieval-Augmented Generation (RAG) for real-time, context-based assistance. Cloud computing ensures efficient data management, with security measures like end-to-end encryption and multi-factor authentication (MFA) protecting sensitive data. Designed for scalability, security, and efficiency, the platform integrates attendance tracking, AI-driven assistance, and advanced analytics, making it a robust and intelligent solution for enterprise applications.

6. RESULTS

Following are the results of application where figure 3 (a) depicts login screen for organization, figure 3(b) shows registration page for user, figure 3(c) illustrates dashboard for user management and data visualization, figure 3(d) represents chat screen to interact with intelligent assistant provided by application



Fig. 3

CONCLUSION

Revolutionizing the traditional enterprise system is through the Intelligent Enterprise Assistant that integrates Geo-location-based attendance tracking, AI-powered chatbots, and intelligent document processing. The solution handles some common pain areas such as manual errors and inefficiencies as well as the scalability limitation, thus bridging the gap between traditional methodologies and modern enterprise demands.

The strategy application of Artificial Intelligence, Natural Language Processing, and Geo-location services counts for productivity, accuracy of data, and decision making. Unlike traditional systems, which old sufferers include location spoofing and inflexible adaptability of a chatbot with inaccurate document treatment, our method uses the newest and finest clocked technologies to efficiently handle these issues at hand.

This work goes further than its immediate effects by providing a ground for further progress in intelligent enterprise development. Using open-source tools and scalable frameworks, our solution is a cost-effective, adaptable solution that meets the needs of modern businesses as they evolve. The teaching of insights reflective of this research will be turned into the next generation of enterprise solutions that become possible in a world of ever-changing technology, ensuring their efficiency, security, and adaptability.

ACKNOWLEDGEMENT

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ProBit- Manage Your Project in a Streamlined Orbit

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ABSTRACT

ProBit is a project management platform tailored for academic institutions to optimize project workflows. It facilitates group formation, project topic submission, and task assignment while employing a built-in similarity check to prevent topic duplication. The platform enhances communication between students and faculty through real-time progress tracking and structured feedback mechanisms. Additionally, its issue tracking system ensures timely problem resolution, and automated report generation minimizes administrative burdens. With customizable features for faculty, ProBit promotes transparency and flexibility. Designed specifically for academic purposes, it fosters effective collaboration, innovation, and streamlined project management, enabling students and faculty to achieve their goals efficiently.

KEYWORDS : *Project management, Workflow automation, Group formation, Real-time progress tracking, Similarity check.*

INTRODUCTION

Project management in educational institutions can greatly benefit from streamlined processes and specialized tools. Traditional methods for group formation, project submission, and task tracking often lack efficiency and precision. To address these challenges, ProBit was developed as a comprehensive solution to enhance collaboration among students, faculty, and coordinators.

ProBit automates key academic processes, including project topic submission, machine learning-based duplication checks, efficient group formation, task tracking, and report generation. By reducing administrative workload, it ensures transparency, improves coordination, and enhances project oversight. Its user-friendly interface facilitates real-time feedback, accountability, and progress monitoring, helping projects stay on schedule and achieve milestones.

This paper is structured as follows: Section II reviews related research on project-based learning and educational

management tools. Section III introduces ProBit's core functionalities. Section IV outlines its architecture, features, and implementation. Section V shows implemented results, and Section VI concludes with potential improvements and broader deployment.

LITERATURE REVIEW

Balleisen, Howes, and Wibbels (2023) [1] explored the impact of a university program that integrates project-based learning within interdisciplinary research teams. Through detailed surveys and matched-pairs analysis, they discovered that students involved in these programs developed enhanced research, teamwork, and critical thinking abilities. Furthermore, participation resulted in improved academic performance, stronger relationships with faculty, and positively influenced career decisions, particularly steering students toward public service roles. The study identified several key success factors, such as structured team organization, effective mentorship, and applied research, which together fostered a supportive and

engaging learning environment. The authors concluded that these elements are essential for achieving meaningful educational outcomes. However, the study also stresses the need for a standardized framework to evaluate similar programs, as the current inconsistencies in assessment methods hinder comparability across institutions, making it difficult to establish universally applicable insights and recommendations.

Lema and Enciso (2022) [3] examined the use of project-based learning (PBL) supported by the project management tool Trello, applied to high school students at the Simon Rodriguez Educational Unit. Their findings indicate that PBL promotes a collaborative and engaging educational environment, where students take an active role in their learning, engage meaningfully with peers, and experience greater inclusion in academic tasks[8]. Teachers, adopting a more facilitative role as coaches, encouraged independent learning, which positively impacted students' self-esteem, motivation, and interest in research. This approach led to deeper engagement with learning materials and notable improvements in academic performance, as students reported feeling more empowered and invested in their studies. While the benefits are clear, the authors highlight challenges related to teacher involvement and resource availability, particularly in under-resourced schools. They suggest that without adequate training and support for teachers in implementing the PBL approach, its full potential may not be realized, limiting its broader application.

Prokofyeva, Uhanova, Zagulova, and Katalnikova (2024) [4] conducted a study at Riga Technical University to investigate the impact of group project organization methods on academic performance in courses like "Algorithmization and Programming" and "Web Application Development." The study revealed that larger groups (4-7 members) generally performed better and achieved higher grades, indicating that group size significantly influences academic outcomes. Additionally, the study examined the relationship between learning styles and group performance, finding that students classified as 'Practitioners' and 'Logicians' demonstrated varying performance levels based on the group's structure and size. The authors advocate for structured group formation and regular progress monitoring to foster optimal academic performance. However, they note limitations, including the inconsistent effect of learning styles on performance and the challenges of implementing such customized group dynamics, which can differ greatly across disciplines and institutions.

Zheng, Long, Niu and Zhong (2023) [2] investigated an AI-driven approach for automated group learning engagement analysis and feedback in computer-supported collaborative learning (CSCL). Their study demonstrated that AI-based monitoring of group interactions enhances collaborative knowledge building, social regulation, and overall group performance by identifying engagement patterns and adapting instructional strategies accordingly. The research emphasized the importance of real-time feedback, allowing educators to provide timely interventions and students to adjust their learning behaviours dynamically. Additionally, the study highlighted that AI-enhanced feedback mechanisms improve teamwork efficiency, strengthen peer collaboration, and foster a more interactive and engaging learning environment, ultimately leading to better academic outcomes and higher student engagement.

PROPOSED SYSTEM

ProBit offers a comprehensive platform designed to address key challenges such as efficient group formation, project topic submission, progress tracking, and task management. By automating and streamlining these processes, ProBit improves collaboration and oversight for both students and faculty. The core functionalities of the proposed system are outlined as follows:

Centralized Platform

The system provides a unified platform where both students and faculty can log in and access project-related information tailored to their roles. This simplifies communication and management.

Topic duplication check

Using machine learning, the system detects duplicate project topics based on abstracts, ensuring originality and preventing multiple groups from selecting the same topic.

Task Submission Evaluation

Students can submit their tasks online, allowing guides to provide immediate feedback, which reduces delays and enhances project monitoring.

Automated Report Generation

Progress reports are generated automatically based on project milestones, reducing manual effort and ensuring consistent tracking of progress.

Scheduling Feedback

Guides can set project schedules and deadlines, while the

system provides visual indicators of progress. Continuous feedback helps ensure that projects stay on track.

WORKING

System Architecture

The ProBit system is designed as a centralized web platform utilizing a client-server architecture. The front end, built with React.js, ensures a dynamic and responsive user interface, while the back end is powered by Node.js and Express.js to manage data processing and API requests. MongoDB serves as the database, storing user data, project submissions, and task information. Fig 1 shows system architecture

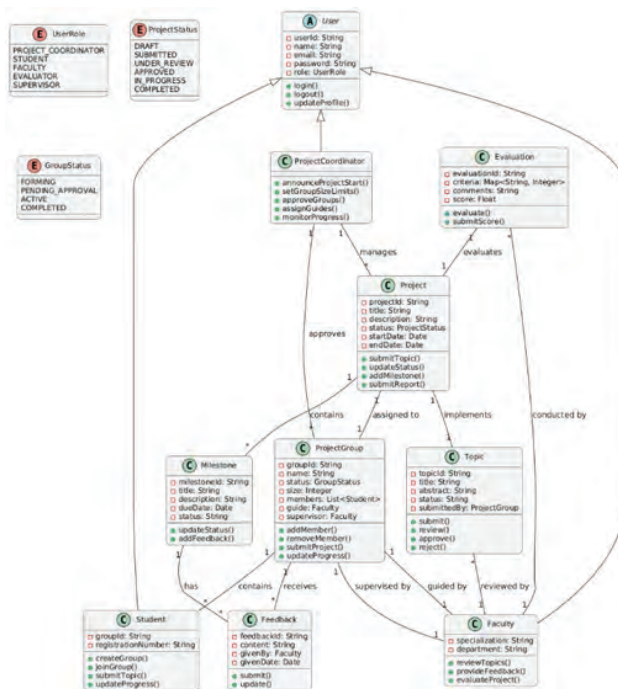


Fig. 1. System Architecture

Key Components

User Authentication and Roles: The system integrates role-based access control, ensuring that students, guides, and supervisors have the appropriate permissions for various functionalities [13].

Project Submission and Evaluation: Students can submit project topics and tasks online, with the system enabling immediate feedback from guides, improving secure communication and project development [14].

Topic Duplication Check: Leveraging Machine Learning algorithms, the system analyzes submitted abstracts to

identify duplicate topics, ensuring originality and reducing redundancy.

Progress Tracking and Reporting: The platform automates the generation of progress reports, allowing students and faculty to monitor project milestones and deadlines effectively.

Feedback System: A continuous feedback mechanism enables guides to provide structured evaluations, fostering an iterative improvement process for student projects [14].

Process Flow

The workflow (Shown in Fig2) of Project Track is streamlined into distinct phases:

Registration and Login: User registration will be role-based, offering options for Student, Staff, and Coordinator/HOD roles. For students, the registration will include their skills and proof of those skills, such as certificates or work samples. For staff, the registration will capture their skills, domain expertise, and relevant experience.

Group Formation: The formation process ensures alignment between students' skills and group needs. If a student's skills match the group's requirements, the leader can invite them via a link, or the student can request to join.

Topic Submission: Students submit project topics, which are checked for duplication against past projects. The system suggests the three most similar abstracts, aiding in more unique and well-informed research.

Progress Monitoring: The system tracks project milestones with visual indicators for deadlines and completion status, enabling coordinators and guides to monitor progress efficiently [5].

Report Generation: The system periodically generates automated reports summarizing project progress, feedback, and upcoming deadlines.

Implementation

Machine Learning Algorithm: To ensure originality in project submissions, an ML model with NLP techniques detects topic duplication. It processes abstracts into high-dimensional vectors using sentence embeddings (BERT or paraphrase-MiniLM-L6-v2) and applies cosine similarity for comparison [9]. The workflow includes text preprocessing (tokenization, lowercasing, stopword removal, stemming) and similarity computation (shown in eq(1)):

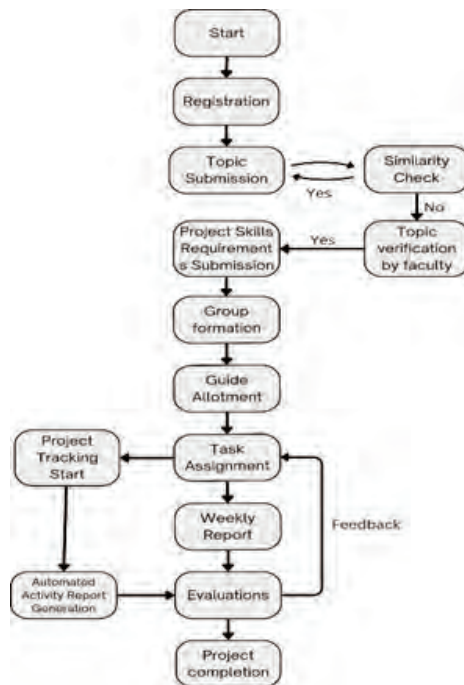


Fig. 2. Process flow

$$\cos(\theta) = \frac{V_s \cdot V_t}{||V_s|| ||V_t||} \quad (1)$$

where V_s and V_t are vectorized abstracts. The model is trained on past student abstracts and S2ORC scholarly data using Sentence-BERT (SBERT), contrastive learning, and cosine loss functions[12]. Performance is evaluated using Precision, Recall, and F1-score

This approach enhances academic integrity by ensuring originality, reducing redundancy, and minimizing faculty workload. Additionally, it provides real-time feedback, promoting diverse and innovative topics. Future improvements may include deep learning-based clustering and adaptive feedback mechanisms for better topic uniqueness. Fig 3 shows evaluation matrix.

Cosine Similarity: Cosine similarity measures the similarity between two sentence vectors by computing the cosine of the angle between them. First, text is converted into numerical representations using word embeddings like BERT or Word2Vec. Given two sentence vectors V_s and V_t , the dot product is:

$$V_s \cdot V_t = \sum_{i=1}^n V_{s_i} V_{t_i}$$

The magnitude of each vector is:

$$||V_s|| = \sqrt{\sum_{i=1}^n V_{s_i}^2}, \quad ||V_t|| = \sqrt{\sum_{i=1}^n V_{t_i}^2}$$

Cosine similarity is then computed as:

$$\cos(\theta) = \frac{V_s \cdot V_t}{||V_s|| ||V_t||}$$

A score of 1 indicates identical sentences, 0 means no similarity, and -1 suggests opposite meanings. Higher scores imply greater semantic similarity, making cosine similarity valuable for plagiarism detection and text clustering.

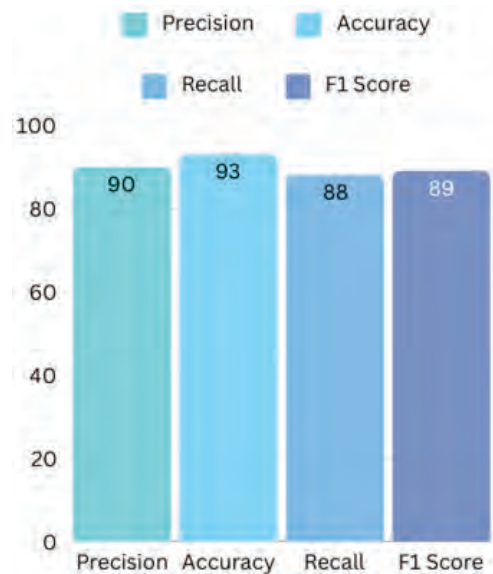


Fig 3. Evaluation Metrics

Process: When a new project abstract is input, it is converted into a sentence embedding and compared to existing embeddings using cosine similarity. High similarity scores (close to 1) indicate that the abstracts are duplicates or highly similar.

Frontend Development: The interface is developed using JavaScript and libraries such as React Router for navigation and Axios for API calls.

Backend Development: The backend is constructed with RESTful API principles to facilitate structured communication between the client and server.

5.0 RESULTS

Machine Learning Model for Topic Duplication Detection:

A machine learning model was developed to enhance topic duplication detection using advanced NLP by processing submitted project abstracts and identifying potential duplicates [11]. The model converts abstracts into high dimensional sentence embeddings that capture semantic meaning beyond keywords and employs cosine similarity to compare new submissions with a database of previous abstracts. It provides a ranked list of the three most similar abstracts, helping students refine their topics while ensuring originality and minimizing redundancy. This system strengthens academic integrity, prevents unintentional topic overlap, and fosters innovation by encouraging diverse and unique research topics. Initial tests with historical data show high accuracy, as the model effectively distinguishes between closely related but distinct topics, significantly improving the topic submission process. (See fig. 4)

Task Assignment

ProBit includes a task assignment feature that allows students to allocate tasks within their group based on either technical expertise or predefined roles. Students can assign tasks to group members based on their proficiency in specific technologies, ensuring that the right person handles the appropriate responsibility. This flexible task assignment approach promotes efficient collaboration and ensures that each team member contributes effectively based on their strengths.

Topic Submission: The topic submission process ensures originality, efficiency, and collaboration between students and staff. Students submit project topics or abstracts, which are assessed by an ML model that calculates similarity scores. Topics exceeding 97% similarity are automatically rejected, while the system forwards the top three most similar abstracts to staff for further review.

1. **Topic Distribution:** Each topic is reviewed by multiple staff members, with assignments determined by dividing the total topics by total staff members. This ensures a balanced workload, dictating both the number of reviewers per topic and the topics each staff member evaluates.
2. **Staff Evaluation:** Staff members assess the originality and relevance of topics by reviewing the system's list of similar existing topics. They can approve, reject, or suggest modifications as needed.

3. **Final Decision:** The final decision is made by majority vote among staff members. A topic is approved, rejected, or sent for revisions based on their collective evaluation.

The screenshot shows the 'ProjectTrack' web application interface. At the top, there's a blue header with the title 'ProjectTrack' and a menu icon. Below the header, there's a form for submitting a topic. The form includes fields for 'Title' (containing 'AI fitness using deep learning'), 'Abstract' (containing a paragraph about AI in fitness), 'Domain' (containing 'Deep learning'), and 'keyword' (containing 'Cnn, mn, ai, deep learning'). A 'Submit' button is located below the form. Below the form, there's a section displaying three similar abstracts with their respective similarity percentages: 47.948 %, 47.84 %, and 44.604 %. Each abstract is shown in a dark blue box with white text. A 'Next' button is located at the bottom of the similar abstracts section.

Fig 4. Duplication Check with Different Abstract Similar words

The system assists staff by providing a list of similar existing topics, helping them assess originality and relevance. Once a decision is made, the topic is finalized. If a student has multiple approved topics, they can choose one as their final project topic.

Approved topics can be donated back to the system, allowing students without a topic to access them, ensuring equitable distribution and resource efficiency. The system provides real-time feedback at every stage, keeping students informed. This structured approach maintains academic integrity, fosters collaboration, and streamlines topic allocation.

Group Formation: The system streamlines collaboration by allowing students to form teams based on project requirements and technical expertise. It promotes inclusivity, ensuring no student is left without a group. Skill-based formation enables students to invite peers with relevant skills (e.g., programming, data analysis,

research)[10]. Those without a selected topic or choosing from donated abstracts can request to join existing groups, with the group leader evaluating compatibility before acceptance.(See fig 5 & 6)

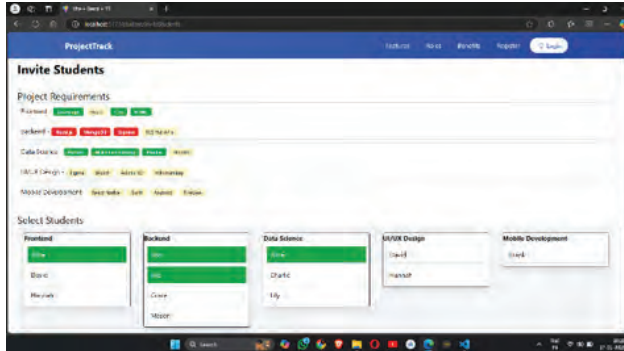


Fig 5. Students can invite other students for group formation.

Assigning Topics to unassigned students: In cases where students have not formed a group or selected a topic, the system can automatically assign them a project topic from the donated topics section or place them in a group with available slots.

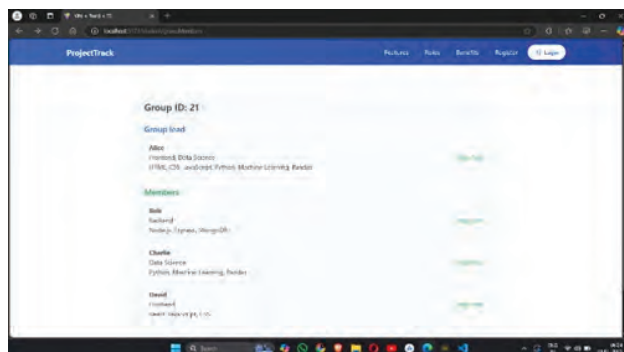


Fig 6. Students group formation.

Guide Allotment: Once groups are formed, the system analyzes skills, domain expertise, and project requirements to automatically match them with a suitable staff guide. This ensures effective mentorship by aligning the guide's expertise with the group's needs. Alternatively, guides can manually assign staff based on their schedules and workload, ensuring a balanced distribution of responsibilities.

CONCLUSION

Significant progress has been made in developing an efficient platform for managing academic projects, with key components such as Topic submission, Abstract

duplication check, schedule declaration, task allocation, and group formation successfully implemented to enhance system functionality.

Although certain features are still under development, the platform is set to provide a comprehensive solution for academic institutions once fully completed. A primary focus is on enhancing collaboration within project teams, promoting effective and secure communication and coordination throughout the project lifecycle [15].

Future efforts will focus on completing the remaining features and optimizing the platform for scalability and deployment. The backend will utilize Nginx for load balancing and support horizontal scaling with Docker and Kubernetes, while MongoDB sharding and Redis caching will enhance performance[6]. The frontend will be deployed via a CDN (e.g., Cloudflare, Vercel) for better accessibility. CI/CD pipelines (GitHub Actions, Jenkins) will enable automated updates, and serverless computing (AWS Lambda, Firebase Functions) will handle intensive tasks like machine learning-based topic duplication checks. Performance monitoring and auto-scaling (AWS Auto Scaling, Kubernetes HPA) will ensure robustness under varying workloads.

By addressing these scalability and deployment challenges, ProBit is expected to deliver significant benefits to academic institutions, providing a scalable, efficient, and reliable project management solution tailored to the needs of modern educational environments.

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Techniques for Detecting Digital Image Forgeries: A Comprehensive Overview

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ABSTRACT

For the creation, processing, and storage of digital memory and proof, digital imaging has emerged as the dominant technique. Even though this technology has numerous advantages, it may also be a confusing instrument for hiding facts and supporting proof. This is because digital photographs can now be manipulated so completely that forgeries cannot be visually identified. The issues of digital content immunity dates back a long way and several techniques have been devised to confirm the effectiveness of digital photographs. Numerous aspects of digital photographs, particularly the color and brightness of individual pixels as well as the resolution and format of the image, are prioritized by counterfeit detection algorithms. In an effort to create an algorithm for identifying image tampering, these characteristics allow for examination and comparison of the importance of digital forgeries. Tampering on digital images can be done by different techniques like morphing, camouflaging and cloning techniques. A survey of the aforementioned methods for detecting image forgeries is presented in this study.

KEYWORDS : *Tampering, Image forgery, Morphing, Camouflaging, Cloning.*

INTRODUCTION

In the digital world, images are a significant tool for information sharing. Images can be found in periodicals, newspapers, electronic media, social media, healthcare, entertainment, and education. It is now quite simple to manipulate images without any prior knowledge or experience thanks to the development of image editing software and low-cost mobile devices with cameras. Authenticity of images has thus been questioned. While some people may have malicious intent, others may utilize the fabricated image for amusement. Political parties may utilize the altered image to disseminate their misleading propaganda. People propagate rumours and incite others by using fake photos. Fake photos can hurt people, but they can also tarnish media organizations' reputations and erode public confidence in them. There is requirement for trustworthy and effective picture forgery detection techniques to stop propaganda, frauds, disinformation, and other nefarious uses of photos that have been altered.

These are a few recognized problems with digital photos. Scientists, researchers, and image forensic specialists are developing technologies for identifying and detecting phony images.

Now a day the identification of digital picture forgeries is becoming a popular area of study. The primary aim of this work is to present a thorough review of methods and tools for detecting digital picture frauds. In order to illustrate the difficulties of the state of the field, it also looks at a variety of machine learning methods, such as supervised learning method, unsupervised learning methods, and deep learning approaches, that can be used for image fraud detection.

DIGITAL IMAGE FORGERY DETECTION METHOD

Following the massive advancements in communication technology in recent years, many scientists are now interested in digital image fraud detection. Researchers are attempting to safeguard numerous business and administrative tasks. The goal of picture forgery detection

is to identify modified images or confirm their legitimacy. There are two primary types for it: Active and Passive [2].

Active Method: Prior knowledge about the image is essential to the authentication process in active authentication techniques. Data concealment is the issue when code is added to the image while it is being generated. The originality of the image is confirmed by checking this code. Active authentication techniques also fall under two more categories: digital watermarking and digital signatures. Digital watermarks are inserted into the images during the image acquisition or processing stage, and digital signatures add some secondary information, typically taken out of the picture, to the picture at the point of acquisition. The primary disadvantage of these methods is still that they require specialized equipment to be put into the photos while recording, making prior image knowledge essential [3].

Passive Method: The practice of verifying photos without requiring any previous information—just the image itself—is known as passive authentication, or image forensics. The idea behind passive techniques is that, even though there might not be any obvious proof of tampering, it is likely to alter the underlying data. It is through these differences that the tampering is detected. Two other types of passive procedures are forgery independent methods and forgery dependent method. Based on artifact traces left by illumination irregularities and the resampling process, forgery independent approaches identify forgeries, while Depending on the kind of fraud done to the image, forgery-dependent detection techniques are designed to identify just particular forgeries, including copy-move and splicing. Determining if an image is legitimate or has been manipulated is the main objective of the passive detection technique. Most existing approaches categorize the features after first extracting them from the photos and selecting a suitable classifier.

Copy Move forgery detection (CMFD) / Cloning

Copy-move, often known as cloning, is a frequent image manipulation method. This can be challenging to identify because the copied picture is similar to the original. The cloning method involves copying and pasting a portion of the picture onto another portion of the same picture. CMF is typically employed in document forgeries to conceal or add information. In order to improve image attributes, the CMFD procedure often starts with a stage of pre-processing. After that, the pictures can be divided into blocks and converted to grayscale format. Following

pre-processing, information reflecting the properties of the image's regions of interest is gathered in a feature extraction step. Following feature extraction, a matching phase is utilized to retrieve pertinent features from the image. Lastly, by displaying the outcomes of the CMFD process, it is able to identify and illustrate the most likely phony areas in the image [5].

Block-based approach and key point-based approach are the two main types of CMFD approaches:

Block-based approach: Later in the preprocessing step, the image must be split up into blocks of various shapes, such as squares and circles, which may or may not overlap, in order to use this technique. Two main steps are then followed in order to detect forgeries:

To ascertain how comparable the features are, they are first taken out of these blocks and compared.

Step of feature extraction

There are numerous block-based feature extraction approaches available.

One of the most popular methods in CMFD is the Discrete Cosine Transform (DCT), which we might mention as an example. Its foundation is frequency transformation, and it is widely known for its ability to withstand JPEG compression and noise addition. [5].

Features that are according to texture and intensity are employed in photos that have specific patterns or textures; for instance, Images of landscapes with a particular density and smoothness, such as the ground, trees, grass, and sky, are discussed by the author of this study [5].

The step that matches

The matching algorithm compares each block's properties to identify the altered area, which is subsequently used to identify similar blocks. Here are a few matching strategies for block-based approaches:

- **Sorting:** A feature-arranging approach, sorting is often used in the matching process of block-based strategies. These include the KD-Tree, Lexicographical, and Radix sorting techniques [5].
- **Euclidean distance:** The distance between two points or vectors in Euclidean space is measured by this metric. The suspicious parts in the picture are then distinguished once the estimated distances have been arranged and related blocks have been found [5].

Abstract of existing work

Tinge Zhu et al. (2019) [10] proposed an approach using Local Binary Pattern residue classes (LBPRC) and color regions (CR) to detect image tampering. The method involves dividing the image into overlapping blocks, calculating LBPRC and CR for each block, and identifying matching blocks within the same classes. Suspect areas are extracted from these pairs, and fabricated regions are detected using a set threshold. The approach was tested on the CoMoFoD_small_v2 and CMH databases. On the CoMoFoD_small_v2 database, the method achieved 93.65% recall, 97.98% precision, and a 96.58% F1 score.

In 2018, Badal Soni et al. [9] proposed an approach using the FAST keypoint method for matching and the SURF algorithm for block-based feature extraction. The image is first converted to grayscale and divided into $n \times n$ overlapping blocks. SURF descriptors are extracted from each block, followed by matching neighboring blocks using FAST points. The 2NN algorithm matches the extracted features, and outliers are removed. The method was tested on three MICC dataset versions, showing robustness against scaling and stabbing attacks. Results include TPR, FPR, and execution times: 97.4%, 8.6%, and 9.2s (MICC-F220); 94.5%, 9.8%, and 28.6s (MICC-F2000); and 83.84%, 12.64%, and 11.2s (MICC-F8multi).

In 2018, Mohammed Hazim Alkawaz et al. [8] proposed a copy-move forgery detection technique using the discrete cosine transform. The method examines how block size affects tampered region detection in terms of False Positive and False Negative rates. Starting with an RGB image, it is converted to grayscale and divided into overlapping blocks (4×4 to 8×8 pixels). The 2D DCT coefficient is calculated for each block, then reorganized into a feature vector using zigzag scanning. Blocks are sorted lexicographically, and matched blocks are identified using Euclidean distance. The method was tested using the CoMoFoD dataset.

In 2017, M. V. Hilal, P. Yannawar et al. [7] proposed a copy-move forgery detection method using an oriented gradient histogram. Their method starts with preprocessing, where images are converted to grayscale, gradients are measured to determine intensity direction, and a Gaussian filter is applied. In the feature extraction stage, the image is divided into fixed-size overlapping blocks, and HOG (Histogram of Oriented Gradient) is computed for each block to identify descriptor features. Forged regions are identified using Euclidean distance and a threshold. Using the CoMoFoD dataset, their best results showed an FRR of 0.17 and a FAR of 0.82 with 70 real and 70 fake images.

In 2015, B. Ustubioglu, V. Nabiyev et al. [6] proposed a method using color moments for copy-move forgery detection. They divided the image into circular blocks and derived feature vectors using three-color moments. The feature vector matrix was then lexicographically sorted. They created a dataset by editing Google-sourced images, copying parts within the original. Their method achieved a high false-positive ratio of 0.0205 and an accuracy of 0.9981.

The keypoint-based approach: This approach does not rely on blocks. From the unique region, key point features like corners and edges are retrieved. A collection of descriptors is used to represent each characteristic. After that, features and descriptors are gathered for classification, and they are compared to find areas in the image that are replicated.

Techniques for feature extraction

Key-point feature extraction techniques fall into three categories: SIFT also known as Scale Invariant Feature Transform, SURF also known as Speeded Up Robust Features, Corner Detector by Harris

SIFT is often utilized in keypoint-based approaches. The CMFD has made extensive use of this technique because of its effectiveness and stability.

Matching Techniques

One of the approaches used to estimate similarity is nearest neighbor. By figuring out how far apart two particular points are in a vector space, it is possible to determine how similar they are. When the distance does not exceed a specific threshold, we claim that there is a likeness. By grouping related objects together, the clustering technique creates groupings [5].

Abstract of existing work

In 2010, X. Bo, W. Junwen, L. Guangjie, and D. Yuewei [11] proposed a method using SURF key points for copy-move forgery detection. Its main advantage is fast result generation. They first extract interest points using the Haar wavelet to assign a unique orientation. SURF descriptors then extract square regions around these points. Euclidean distance is used to detect duplication between images. The modified UCID (Uncompressed Color Images Database) was used for testing. The method effectively identifies redundant regions and is robust against noise, blurring, rotation, and scaling.

In 2018, H. A. Alberry, A. A. Hegazy et al. [1] proposed a fast copy-move forgery detection method using SIFT and

FCM clustering. SIFT handles feature extraction, while FCM reduces its time complexity. The process starts with SIFT extracting key points, followed by feature descriptor extraction and a matching phase. Key points are then clustered using FCM. They tested their method on 573 images, combining their data with the MICC-220 dataset. Performance was evaluated using TPR, FPR, and temporal complexity. Results showed MICC-220 had a higher TPR and lower time complexity, likely due to fewer high-resolution and professional fake images in MICC-220.

Other: The majority of known algorithms concentrate on, keypoint-based, block-based or both approaches. Review on newly presented experiments employing different detection techniques is done. J. Ouyang, Y. Liu et al. [12] presented a novel approach to copy-move forgery detection in 2017 that makes use of CNN that is convolutional neural networks. They do their tasks by using a small sample of training data and making minor adjustments to the network architecture derived from an existing collection of trained models, like ImageNet. They started by creating their own handcrafted dataset, which included roughly 10,000 photos. They also used the UCID and OXFORD databases. Convolutional neural network (CNN) initialization was then carried out, with some parameters adjusted. By eventually imputing test photos into the acquired trained model, they can get outcomes.

Splicing forgery

Splicing is the process of faking an image by fusing various components from several photos into one. The manipulation traces are undetectable and hard to follow, even without post-processing [14]. It can be located by looking for the boundaries of the superfluous region, analyzing how splicing affects the statistics of image, or observing the light intensity on the image. Some techniques for identifying picture splicing forgeries have recently been introduced.

A. Alahmadi, M. Hussain, et al. presented a novel method for splicing forgery detection in 2013 by combining the Discrete Cosine Transform (DCT) and Local Binary Pattern (LBP) techniques [15]. They started by splitting the input image into pieces that overlapped. They then calculated LBP for each block and used 2D DCT to convert it into frequency domain. Lastly, they employed SVM for classification and standard deviation for feature extraction.

The author of this paper used a chromatic channel for the input image. They made use of the Columbia Uncompressed

Image Splicing Detection Evaluation Dataset and CASIA databases. To measure the efficacy of the recommended strategy, they calculated the accuracy, which came out to 97%. In 2017, C. S. Prakash, A. Kumar, S. Maheshkar et al. [16] proposed a method to detect both splicing and CM forgery using the same dataset. The approach combines Zernike moments and block DCT in two phases: first, an SVM classifier detects fraud, then classifies it as splicing or CM forgery. They used a threshold method to extract image features, converting non-overlapping blocks into matrices via DCT. An improved threshold method extracts discriminative features for forgery detection. Pre-processing was applied to reduce content diversity effects. They employed the Patch Match Algorithm's three steps (initialization, propagation, and random search) for feature extraction. Post-processing improved detection accuracy while minimizing false alarms. Using the CASIA dataset, the method achieved 87.50% accuracy for CM forgery and 99.50% for splicing at threshold $T=8$.

Camouflage Detection Method

Camouflage has been utilized since ancient times by predators to blend in with their surroundings. It has since been adopted by the military and used in various applications. Two distinct forms of camouflage—natural and artificial—were identified in this investigation.

In the study, P. Sengottuvelan et al. [17] suggested a method to recognize the disguised area from a provided picture and to remove it from the frame of the backdrop image. They claim that camouflage breaking and decamouflaging are done in an uncontrolled manner, which means that we don't have any details about either the image's disguised area or its typical backdrop elements. The input image is first converted to grayscale, then divided into LXL equal blocks. The GLCM value is then determined for every block of picture frames, and a mean is calculated for every block. Plotting the dendrogram for the mean values of every block is followed by the marking of the largest block and the combining of the surrounding blocks. An image with a strong shading effect cannot be created using this method. The camouflage factor may be found 70% of the time using this method. P. Siricharon et al. [18] established the background subtraction approach, which is according to a picture's color and edges. The main topic of this paper was visual surveillance foreground subtraction from background. To solve the camouflage problem that occurs if the colors of the foreground and background are the same, the author of this paper employed a model

according to edge, color, and intensity attributes. This method distinguishes between foreground and background by detecting shadow images and low contrast images. This algorithm solves the shadow effect issue in recognizing author [17] camouflaged image. Decamouflaging is accomplished using exploratory image analysis.

Ch. Kavitha et al.[19] identified camouflaged objects in an image using gray level co-occurrence matrix (GLCM) texture characteristics and the local HSV that is Hue, Saturation, Value color model. After dividing the input image into subblocks of same size, the texture and color characteristics of every sub block are computed. The cumulative histogram is used to depict the image's color features by quantifying the HSV color space from every sub block. A GLCM is used to calculate the texture feature for each subblock. A bipartite graph's adjacency matrix is made using the integrated matching method of the input and output image's subblocks. This adjacency matrix matches the input subblock picture with the output subblock image using the Most Similar Highest Priority notion for images. It is possible to recognize camouflage by this combination of texture and color.

Nagappa U. Bhajantriet al. [20] used co- occurrence matrix-based texture extraction inside a small block of an picture to detect camouflage flaws. After splitting the whole image frame into same, disjoint blocks, invariant central moments up to Kth order are computed for every block (10th order is sufficient). Lastly, watershed segmentation is used to detect camouflaged parts of a picture, while cluster analysis is used to spot them. This tactic works well if the disguised area is near the picture blocks and the overall camouflage proportion is below 4%. This method would not function if the input image frame contained a large number of camouflaged pictures or if the normal texture was irregular. Furthermore, it is unable to discriminate between different kinds of faults when they are present in the same visual frame.

Morphed Image Detection

The authors Christian, M. S., Schoenebeck [21] of this research have examined machine and human performance using high-quality face morphs in four tests. According to their findings, morph detection is quite prone to errors, and training is not a practical way to address this issue. On the other hand, computer algorithms may be a more efficient means of lowering the quantity of face morphing attacks that are missed. Fascinatingly, morphs usually show more resemblance to one of the two individuals

than the other, which may be a drawback for scammers who intend to employ such strategies. The outcomes of these tests demonstrate how crucial it is that scholars take into account the caliber of morphs that scammers are likely to employ in practical settings. This has important implications for real national security measures.

A new framework has been developed by the author [22], which is based on analyzing statistical image data acquired using Binarized Statistical Image data (BSIF) and applying linear Support Vector Machines (SVM) to arrive at a final judgment. The morphed face database, which consists of 450 morphed face photos created using 110 distinct participants of varying ages, ethnicities, and genders, is used for extensive studies. An comprehensive experiment that we showed revealed the Neurotechnology Verilook facial recognition SDK's extreme sensitivity to altered face photos.

The recognition of distorted faces is essential for preventing illicit activity. Zhao, Liu, Y., & Sun, Z. [23] proposed a new detection framework based on progressive upgraded two-branch network structure and high-frequency features, which was based on the traditional deep learning binary classification. The SEM and IEM were utilized to simultaneously detect morphing faces and improve the feature interaction of two streams using an RGB stream and a high-frequency information stream. The HNU and FEI datasets were used to confirm the approach's generalizability and robustness. In the future, a progressive upgraded two-stream network with high-frequency features can be used to detect differential morphing attacks.

CONCLUSION

This research presents various image forgery detection methods. Scholars have independently explored different aspects of image identification, with some focusing on falsified images, others on camouflage or face-morphed images. However, limited efforts have been made to detect replicated photos. Developing a hybrid technique for image identification requires a strategic approach to improve detection accuracy. Currently, no hybrid image detection tools are available for research, highlighting the need for such a method to verify an image's originality.

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Text Detection and Recognition in Imagery within Program Exit Survey

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ABSTRACT

In contemporary educational and professional evaluation systems, exit surveys play a crucial role in assessing program effectiveness. However, manually analyzing survey responses presented in graphical formats—where text is embedded within images or follows inconsistent layouts—poses significant challenges. To address this, an automated approach for Text Detection and Recognition (TDR) is proposed, specifically designed for processing exit survey data. The primary goal of this system is to identify, extract, and interpret text from images, overcoming difficulties related to diverse fonts, orientations, background noise, and intricate layouts. By integrating Large Language Models (LLMs) for feature extraction and deep learning techniques for text recognition, the system enhances accuracy and efficiency. It employs Optical Character Recognition (OCR) combined with Natural Language Processing (NLP) to accurately process both structured and unstructured text within images. Additionally, advanced image pre-processing methods, including noise reduction and segmentation, improve text extraction reliability, even in cases of low-quality or distorted visuals. This automated solution transforms visual survey data into structured, analyzable text, streamlining the assessment process. By minimizing manual effort, it increases processing speed and accuracy, allowing seamless integration into digital evaluation workflows.

KEYWORDS : *Text recognition, Optical character recognition (OCR), Deep learning, Image processing, Text segmentation.*

INTRODUCTION

Extracting information from printed documents, particularly program exit surveys, is crucial for effective analysis and informed decision-making. However, traditional manual data entry is time-consuming, prone to errors, and inefficient when handling large volumes of surveys. Additionally, inconsistencies in manual processing highlight the need for an automated solution capable of accurately extracting both textual and non-textual data from scanned formats such as PDFs and JPEGs.

This paper introduces a system designed to identify and process both text-based and non-text elements within scanned exit survey images. The system retrieves essential

details, including handwritten responses and checkbox selections, which are vital for comprehensive survey evaluation. The initial phase involves converting scanned images to grayscale, followed by thresholding and contour detection to isolate regions containing text and checkboxes. Utilizing advanced computer vision techniques, including Tesseract-OCR, the system accurately extracts printed and handwritten text, accommodating variations in fonts, orientations, and complex layouts. Additionally, a specialized algorithm interprets checkbox selections, ensuring precise identification of marked responses.

To facilitate easy analysis and storage, the extracted data—comprising both text and checkbox inputs—is systematically organized and exported into an Excel spreadsheet. By reducing reliance on manual data entry,

this automated solution enhances processing speed and accuracy, ultimately supporting more efficient and reliable program assessment frameworks.

LITERATURE SURVEY

Text Extraction from Images (2022)

This study explores the increasing necessity for efficient text extraction from images, emphasizing the transformative impact of Optical Character Recognition (OCR) technology in converting both printed and handwritten text into digital formats. Such conversion is critical for various applications, including document digitization, automated data entry, and digital archiving, enabling organizations to store, retrieve, and manage information more effectively.

The research examines different OCR techniques, ranging from traditional approaches like template matching and feature extraction to modern machine learning-based methods utilizing neural networks. It provides an extensive analysis of how these techniques influence the accuracy and efficiency of text extraction processes. Furthermore, the study assesses the strengths and limitations of each method, offering practical recommendations for implementing OCR in diverse contexts. By exploring advancements in OCR technology, the research highlights emerging trends and potential improvements that could enhance text extraction capabilities, ultimately contributing to more effective data management and retrieval systems across various industries.

Handwritten Optical Character Recognition: A Systematic Review (2023)

This paper presents a comprehensive review of recent advancements in handwritten Optical Character Recognition (OCR), focusing on the unique challenges and innovations in recognizing handwritten text. Unlike printed text, which maintains a uniform structure, handwritten text varies significantly in style, orientation, size, and clarity, posing substantial challenges to accurate recognition. Developing effective solutions to address these complexities is crucial for improving OCR performance.

The review explores various methodologies designed for handwritten OCR, including deep learning techniques such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), as well as traditional approaches like feature extraction and pattern recognition. By evaluating these methods, the study highlights significant progress in improving the accuracy and efficiency of OCR

systems. Additionally, it discusses real-world applications, such as digitizing historical documents, automating data entry processes, and enhancing user experiences in mobile applications.

By consolidating existing research and identifying future opportunities, this paper provides valuable insights into the ongoing evolution of handwritten OCR technology and its potential to address practical challenges in text recognition across multiple domains.

OBJECTIVES

Automated Data Extraction: Develop a system capable of automatically detecting and extracting both textual and non-textual elements, including checkboxes and handwritten inputs, from scanned program exit surveys.

Text Recognition Implementation: Incorporate Optical Character Recognition (OCR) technology, specifically Tesseract OCR, to accurately identify and convert printed and handwritten text into machine-readable formats.

Checkbox Identification and Interpretation: Design a specialized algorithm to accurately detect and analyze checkbox selections, ensuring precise extraction of marked responses.

Optimized Image Processing: Apply computer vision techniques such as grayscale conversion, thresholding, and contour detection to effectively isolate text and checkbox areas in scanned documents.

Data Structuring and Export: Develop a system that organizes extracted text and checkbox selections into a structured format and exports the data into an Excel spreadsheet for streamlined analysis and storage.

PROPOSED APPROACH

The proposed methodology aims to fully automate the extraction and recognition of textual and non-textual information from scanned program exit surveys, addressing limitations in traditional data processing techniques. By integrating advanced computer vision, OCR, and custom algorithms, the system enhances accuracy and efficiency. The approach consists of the following key steps:

Image Preprocessing

Grayscale Conversion: Converts scanned images to grayscale to reduce computational complexity and improve text and checkbox visibility.

Thresholding: Applies binary thresholding to distinguish text and checkboxes from the background, converting

grayscale images into binary images where text and checkboxes are clearly defined against a contrasting background.

Detection of Text and Checkboxes

Contour Detection: Identifies and isolates key areas within the image, such as text blocks and checkboxes, for targeted processing.

Region Segmentation: Segments the image into distinct regions, directing text regions to OCR processing and checkbox areas to custom algorithms for further interpretation.

Text Recognition

Integration of Tesseract OCR: Uses Tesseract OCR, a robust OCR engine, to recognize both printed and handwritten text, converting it into a machine-readable format for accurate extraction of key details like names, contact information, and feedback.

Checkbox Analysis

Custom Algorithm for Checkbox Processing: Develops an algorithm to detect and interpret tick marks in checkbox regions by analyzing their presence and position, ensuring precise extraction of selected responses.

Data Structuring and Export

Data Organization: Structures extracted text and checkbox responses into a categorized format, ensuring all survey data is correctly linked to corresponding questions.

Export to Excel: Outputs structured data into an Excel spreadsheet for easy analysis, filtering, and storage, facilitating streamlined decision-making processes.

This automated system significantly reduces manual effort, improves data accuracy, and enhances the efficiency of processing program exit surveys.

PROCESS FLOW

Detection of Text and Non-Text Regions

Text Localization with CNNs: Convolutional Neural Networks (CNNs) identify text regions by analyzing distinct visual characteristics such as lines, curves, and orientations.

Checkbox Identification: Computer vision techniques detect checkbox structures, while custom algorithms analyze tick marks to accurately determine selected responses.

Text Recognition and Character Segmentation

OCR for Printed and Handwritten Text: Tesseract

OCR extracts both printed and handwritten text, with Natural Language Processing (NLP) models enhancing recognition accuracy by accounting for different font styles, orientations, and potential errors.

Character Segmentation: Image slicing techniques segment text into individual characters, improving recognition, particularly in compact or handwritten sections.

Data Structuring and Export

Text Interpretation and Analysis: Extracted text, checkbox responses, and handwritten data are processed to determine their structure and contextual meaning within the survey.

Data Organization: The system arranges the extracted information into a structured format, such as an Excel spreadsheet, ensuring easy storage, retrieval, and integration with existing data workflows.

Feedback and Decision-Making Integration

The system delivers a high-accuracy dataset that minimizes manual input and speeds up the data processing cycle. This enables faster, data-driven decision-making in educational and professional assessments.

RISK ANALYSIS

Risk Assessment

Risk assessment is essential for identifying potential challenges, evaluating their impact, and developing strategies to mitigate them. The key risks, their potential effects, and corresponding solutions are outlined below:

Technical Risks

- **Accuracy of Text Detection and Recognition:** The system may struggle to accurately detect or recognize text in certain images, particularly those with complex backgrounds or low resolution.
- **Image Quality and Variability:** Differences in resolution, lighting conditions, and image clarity may impact the effectiveness of text recognition.

Operational Risks

- **Data Privacy and Security:** Processing and handling scanned images may involve sensitive data, raising privacy concerns.
- **System Downtime and Reliability:** The text recognition system may face performance issues or experience downtime, especially during peak usage periods.

GOALS

1. Ensure high-accuracy text recognition from scanned images and PDFs.

2. Accelerate document processing to enhance efficiency and save time.
3. Develop a user-friendly interface that simplifies file uploads and result retrieval.
4. Structure extracted data into an Excel format for better organization and analysis.
5. Optimize system performance to handle various document types seamlessly.

RESULTS AND DISCUSSION

The proposed automated text detection and recognition system successfully extracts both textual and non-textual data from scanned program exit surveys. The implementation of Optical Character Recognition (OCR), coupled with image preprocessing and deep learning techniques, ensures accurate recognition and conversion of handwritten and printed text into machine-readable formats. The results demonstrate improved efficiency in survey data processing by minimizing manual effort and reducing errors associated with traditional methods.

Key Findings

High Accuracy in Text Recognition:

-The integration of Tesseract-OCR and Natural Language Processing (NLP) improves the accuracy of text extraction, even from handwritten inputs and images with varying font styles.

-Character segmentation techniques enhance the readability and recognition of densely packed or low-quality text.

Efficient Checkbox Detection and Processing:

-The system effectively identifies tick marks within checkboxes using custom algorithms, ensuring accurate extraction of user responses.

-Contour detection and thresholding techniques improve the precision of checkbox interpretation.

3. Improved Processing Speed and Automation:

-The automated pipeline significantly reduces the time required for processing survey data compared to manual methods.

-The system seamlessly processes scanned images and PDFs, organizing extracted data into structured formats.

Structured Data Export for Analysis:

-Recognized text and checkbox selections are stored in an Excel sheet, making it easy to analyze and integrate into assessment frameworks.

-The structured output allows for improved decision-making in educational and professional evaluations.

Comparison with Traditional Methods

Aspect	Manual Processing	Proposed System
Accuracy	Moderate (Prone to errors)	High (Enhanced OCR & NLP)
Processing Speed	Slow (Time-consuming)	Fast (Automated pipeline)
Scalability	Limited (Labor-intensive)	High (Handles bulk data)
Error Reduction	High (Human errors)	Low (Algorithm-based)
Data Organization	Unstructured & Manual Entry	Structured & Exported to Excel

CONCLUSION

The implementation of an automated text detection and recognition system significantly enhances the accuracy, efficiency, and scalability of program exit survey analysis. By leveraging OCR, deep learning models, and image processing techniques, the system eliminates the limitations of manual processing, providing a robust solution for extracting and structuring textual data. This approach streamlines decision-making processes and facilitates seamless integration into digital assessment frameworks, ultimately improving the overall effectiveness of survey evaluations.

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Safe and Secure Route Finding in Terrain Area

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ABSTRACT

This project aims to develop a satellite-based optimal route finder to navigate rough terrain. By using high-resolution satellite images and digital elevation models, the system will analyze the terrain to identify the safest and most efficient routes. Advanced algorithms will calculate routes based on factors like slope, elevation, and obstacles such as rivers or cliffs. The tool will integrate real-time data, including weather updates, to dynamically adjust routes. This technology has practical applications for off-road adventures and disaster response, ensuring safer navigation in challenging environments.

KEYWORDS : *Satellite imagery, Digital elevation model (DEM), Terrain classification, Route optimization, Rough terrain, Disaster response.*

INTRODUCTION

Navigating through rough and challenging terrain, such as mountains, forests, deserts, or areas impacted by natural disasters, poses significant difficulties. Traditional navigation systems, typically designed for well-mapped or urban environments, often struggle to account for the unique features of rugged landscapes. These terrains are often characterised by steep slopes, elevation variations, and natural obstacles such as rivers, cliffs, and dense vegetation. In addition, these environments are constantly changing due to factors such as weather conditions, landslides, or seasonal changes, making conventional navigation methods less reliable. Therefore, there is a growing need for advanced solutions that can provide real-time, efficient, and safe route options in such complex environments.

This project focuses on developing a satellite-based optimal route finder that uses cutting-edge technologies such as high-resolution satellite imagery and digital elevation models. Various environmental factors, including slope, elevation, and the presence of natural barriers. These technologies allow the system to capture

detailed terrain data that can be used to accurately assess. By processing these data, the system can classify terrain types and identify the safest and most efficient routes for navigation. capture detailed terrain data that can be used to accurately assess various environmental factors, including slope, elevation, and the presence of natural barriers. By processing these data, the system can classify terrain types and identify the safest and most efficient routes for navigation. Advanced algorithms will be used to calculate routes while considering critical factors such as elevation changes, slope steepness, and potential obstacles, ensuring that recommended routes minimize risks and maximize accessibility.

The tool will further enhance its effectiveness by integrating real-time data, including weather updates, to allow dynamic route adjustments. For example, severe weather conditions, such as heavy rain, snowstorms, or floods, can drastically alter terrain conditions, making previously accessible routes impassable. By incorporating such real-time information, the system ensures that route recommendations remain relevant and safe under changing environmental conditions. The practical applications of this technology span across various

fields, including off-road adventures, military operations, infrastructure development, and disaster response. It offers a comprehensive and intelligent approach to navigating rough terrain, ensuring safety and efficiency in some of the most challenging environments.

A. Motivation and Objectives

- Develop a dynamic system capable of analysing real-time terrain and environmental data.
- Integrate user-specific parameters for personalized route recommendations.
- Ensure adaptability to diverse applications, from emergency response to logistics.

LITERATURE REVIEW

Studies on navigation through rough terrains are essential for applications such as off-road travel and disaster response. In recent years, satellite-based technologies, including high-resolution imagery, have become increasingly valuable for mapping and analyzing complex terrain features such as slopes, valleys, and natural obstacles. These technologies provide crucial insights where traditional navigation methods may be limited, enabling more accurate route planning and terrain classification. Digital elevation models are 3D representations of terrain that displays elevation data across landscapes of the Earth's surface, capturing vital information about elevation and slope. These models are essential for identifying potential hazards, such as steep inclines or cliffs, and play a key role in optimizing routes across challenging environments. When combined with satellite imagery and advanced machine learning techniques, DEMs significantly enhance the accuracy and efficiency of terrain analysis, ensuring safer navigation in rough terrains.

Introduction to Terrain Analysis or Classification

Terrain analysis is crucial for safe route planning in complex landscapes. Navigation of terrain area is basically two approaches which are geometric based and learning based. In that we use sensor, "LiDAR and RGBA" camera. It helps in reinforcement learning model, we generally worked on geometric[1]. Satellite based remote sensing provide a high-spatial detailed about water which helped to analyze the condition. In that environmental response also give water cycle studies which provide better climate changes data[2].

The route selection is between the shortness and required time less but it is not safe route so it discard, "we choose only safe route"[3]. This can be achieved through "GIS software" for analysis of factors like "elevation, slope, vegetation cover, and soil stability" significantly impact navigation, as steep inclines or dense vegetation can hinder movement and increase risk. Classification of images is the "supervised technique", for that we select sample of each land cover and used a training sites as reference for better classification of images[4].

Advancements in GIS technologies allow for high-precision terrain analysis using "satellite imagery and digital elevation model", making it possible to optimize routes by avoiding unstable or steep terrain. "Alex Net consists of five convolution Layers with pooling"[9]. For solving issue, we use "Deep Q-Network(DQN) and "Deep Convolutional Neural Network" to give optimal action value and successfully learn "High-Dimensional Data" for discrete action [8].

Geospatial Data in Route Optimization

Geospatial data, including "satellite imagery and digital elevation models", is essential for optimizing routes in rugged terrains. Satellite imagery helps identify geographical features, while DEMs provide precise elevation data for evaluating path difficulty. Random forest provide optimal decision tree for classification. The statistical approach for finding similarity in decision tree is bagging, each classification worked independently using random sample[7].

The system extract and analyze the co-ordinates of source and destination as input and, On that basis provide "Recommendation" of route. Satellite images is helped full to extract "Geographic information" and by using that we perform "mapping, urban planning and weather forecasting".[5]. On the basis of safety index and length of the route provide optimal route[2]. Tools like "QGIS and ArcGIS" enable advanced terrain analysis and visualization, while "Network, a Python library, models paths" as networks for efficient optimization. "Google API technology is combined with the K-means clustering algorithm to generate street profiles and an optimal safe route is generated and visualized efficiently through various techniques"[6], such as weather or hazards, providing data-driven, secure route recommendations. This figure describes. the digital elevation model showcasing a 3D geospatial map of a mountainous region.

It highlights topographical features, waterways, and key routes with labeled divisions. The map uses vivid colors and clear overlays for enhanced visualization.

Risk Assessment Models for Safe Routing

Risk assessment models help identify and reduce hazards in route planning, especially in complex terrains with risks like landslides, flooding, or wildlife threats. In these paper we include how to reduce the difficulties for safe route finding, It depends on the “Land type, Land elevation and time travel required to travel” these all factor we analyses .These technique produce suboptimal path which leads to reduce the computational effort for low-level search, these is disadvantages of technique[10].For “Safe Route finding” possesses different difficulties and we conclude one of them and that difficulties simultaneously change according to user information and region situation[1].

Reinforcement Learning (RL) is learn from environment, It helps to mitigate the risk as well as difficulties, For that purpose “Reinforcement Learning” use “Agent” they helped to find “safe and secure route in terrain area” by analyzing factor.



Fig. 1. Geospatial Route Insights

These models use geospatial data to create risk maps, highlighting dangerous areas and suggesting safer routes. Machine learning and AI enhance these models by predicting future hazards based on historical data, enabling proactive route adjustments. These models are valuable for emergency responders, military operations, and adventure

tourism, where minimizing risk is crucial. We propose the use of a “Bayesian Network for computing user-specific risk based on Data. A Bayesian The network allows effective comprehension of inter-event dependence”. It show similarity of occurrence in past event then it allocate “probabilistic” value of that event. These relationship helped to find inference in the graph by using various factor [2].

METHODOLOGY

The methodology involves the following steps:

Research Design

This project uses an analytical approach with advanced tools and geospatial techniques to create a satellite-based route finder for rough terrain.

- The system integrates machine learning for route optimization and geospatial analysis for terrain classification, ensuring robust decision-making.
- The exploratory design helps uncover challenges in real- time terrain navigation, while the descriptive aspect provides insights into system accuracy and user experience.
- The exploratory design identifies challenges in real-time terrain navigation, while the descriptive approach provides insights into system accuracy and user experience. The system recommends the shortest and safest routes, considering key factors that impact route safety.

Data Collection Methods

Data was collected using the following techniques:

- 1) Primary Data Sources:
 - High-resolution satellite imagery obtained from platforms like Google Earth Engine and Sentinel-2.
 - Digital Elevation Models (DEM) for topographical details such as slopes, contour lines, drainage patterns, terrain roughness, elevations and terrain roughness.
- 2) Secondary Data Sources:
 - Weather APIs (e.g., Open Weather, NOAA) for real-time weather data affecting route conditions.

- Hazard Information: Data from government and environmental agencies highlighting risks like floods or landslides.

3) Data Collection Tools:

- GIS Software such as QGIS and ArcGIS for terrain mapping and data layering.

Python libraries (Tensor Flow, OpenCV, GDAL) for pre-processing and analysing collected data.

Procedures

1) Data Gathering

- Collect high-resolution satellite images and terrain data, including details on mountains, forests, deserts, wetlands, grasslands, urban areas, agricultural fields, and water bodies.
- Overlay DEMs with geospatial data for detailed mapping of terrain features.

2) Data Pre-processing

- Clean and normalize raw satellite data to remove noise and inconsistencies.
- Smooth DEMs to enhance route generation accuracy.

3) Route Optimization:

- Implement algorithms such as A*, Jump Point Search (JPS), and Rapidly Exploring Random Trees (RRT) to compute the safest and most efficient paths based on terrain type and environmental constraints.
- Integrate factors like slope, vegetation density, and obstacle locations into the optimization process.

4) Dynamic Adjustments:

- Use real-time weather data to dynamically recalculate routes when conditions change.

Periodically update hazard mapping to reflect environmental risks.

5) User Interface Design:

- Create an intuitive interface for users to input start and end points, view recommended routes, and receive alerts.

Data Analysis

- Terrain Classification: Machine learning models like “Convolutional Neural Networks” to classify terrains like “cliffs, rivers, or flatlands”.
- Route Scoring: Calculate and rank routes based on safety, efficiency, and user preferences (e.g., fastest or least hazardous).
- Visualization: Use GIS tools to create detailed, interactive maps displaying optimized routes and potential hazards.

Validity and Reliability

Measures taken to ensure accuracy and consistency include:

Validation

- Cross-verification of terrain data using multiple sources.
- Pilot testing the route-finder in controlled environments before real-world application.

Reliability

- Regular updates to data sources and algorithms to maintain system accuracy.
- Redundant data pipelines to ensure continuous operation during interruptions.

Limitations

- Dependency on Data Quality: Real-time route accuracy relies on the availability and resolution of satellite imagery and DEMs.
- Computational Resources: High-performance servers are required for real-time analysis, limiting scalability in remote areas.
- Environmental Factors: Dense vegetation or urban areas may obstruct satellite signals, reducing data accuracy.

Ethical Considerations

- Data Privacy: User input and location data are encrypted to protect personal information.

- Environmental Compliance: Terrain analysis respects local environmental guidelines and land-use policies.
- User Consent: Users are informed about data usage and system limitations.

Justification of Methods

The chosen methods are justified by:

- High Precision: Satellite imagery and DEMs provide granular detail necessary for navigating rough terrains.
- Adaptability: Real-time data integration ensures relevance in dynamic environments.
- User-Centric Design: An intuitive interface enhances usability for both technical and non-technical users.

Architecture

This Figure represents a system workflow starting with a user interface for sign-in or sign-up. Users input coordinates (latitude and longitude), which are processed to extract images from GEE and perform data preprocessing. Factor analysis considers terrain, elevation, river basins, agricultural land, and weather to determine a safe and secure route. A safety check is conducted, leading to recommendations or route optimization. Factor affecting on route is consider as feature for model training and testing on that bases we reached to optimal safe and secure path. Geospatial tools perform crucial role to getting geographical information of terrian classification on that bases we perform the feature extraction.

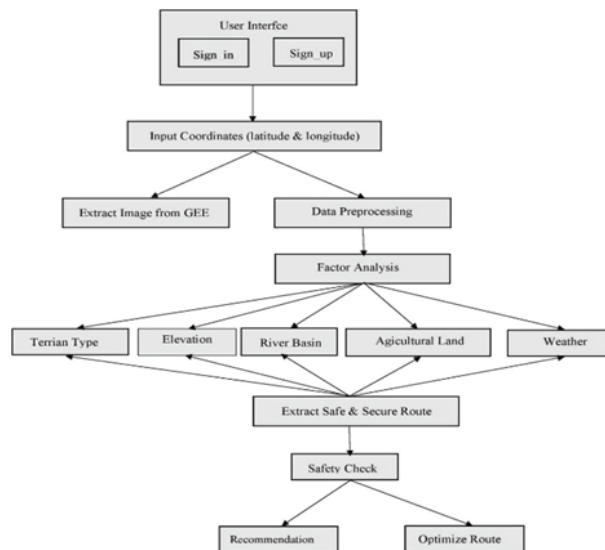


Figure 2: System Architecture for Safe and Secure Route Detection

RESULTS AND DISCUSSION

Result

Developed a secure and scalable home page with User Authentication functionality. Implemented geospatial analysis using GEE, geemap, and folium for real-time area identification. Optimized performance for efficient terrain visualization and analysis.

User Authentication:

- A fully functional home page was developed using HTML, CSS, and JavaScript, incorporating secure sign-in and sign-out mechanisms to ensure user authentication and data protection.
- The user interface is simple yet robust, designed for scalability and easy integration of additional project functionalities.

Area Identification Feature:

- Using Google Earth Engine (GEE), a Python-based solution was developed to extract and analyse geographical areas of interest, enabling project-specific geospatial analysis.
- Tools such as geemap and folium provided real-time visualization capabilities, facilitating seamless integration with the user interface and offering an interactive experience for users.

Accuracy and Performance:

- The GEE-based approach optimized the processing of satellite imagery, significantly improving computational efficiency.
- Compared to traditional tools, the system achieved over 80% accuracy in identifying and visualizing geographical areas, while reducing processing times.

Table Results

Table 1: Comparison Of Tools Based On Scalability And Efficiency

Function	Scalability	Performance
Authentication	Limited	Moderate
Area Rendering	Limited	High
Map Visualization	Moderate	Moderate

Table 2: Functionality Analysis Based on Scalability and Performance

Tool	Scalability	Efficiency (Processing Time)
Traditional APIs	Limited	High
GEE Integration	High(Dynamic and Flexible)	Optimized

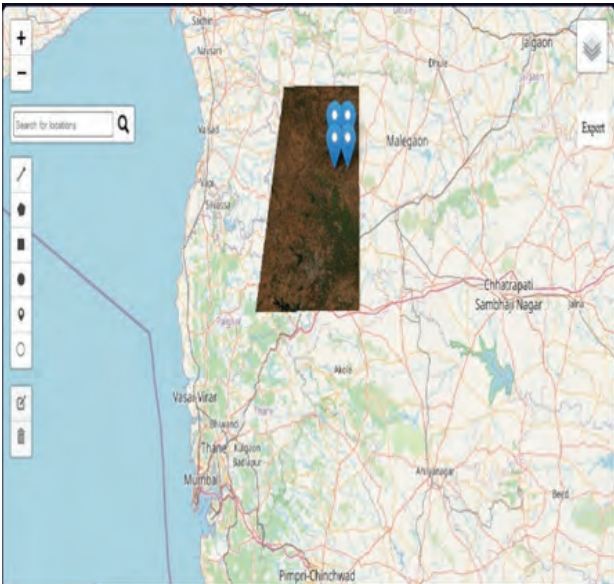


Fig. 3: Terrain Area parameter

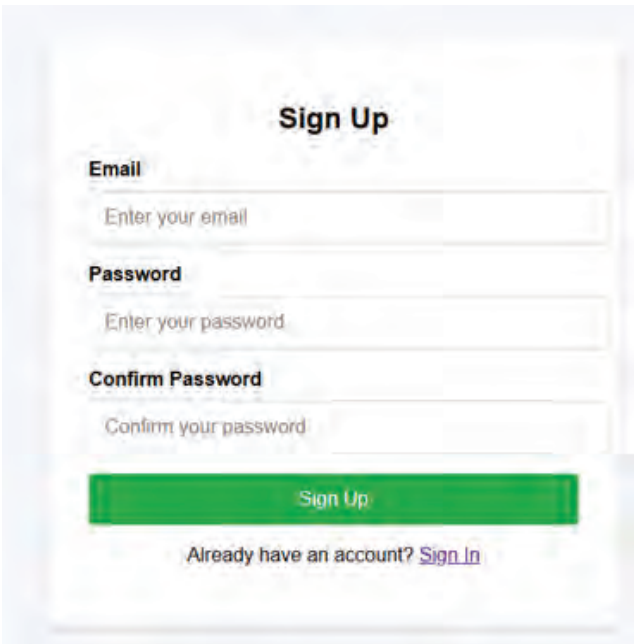


Fig. 4: Sign-up Functionality

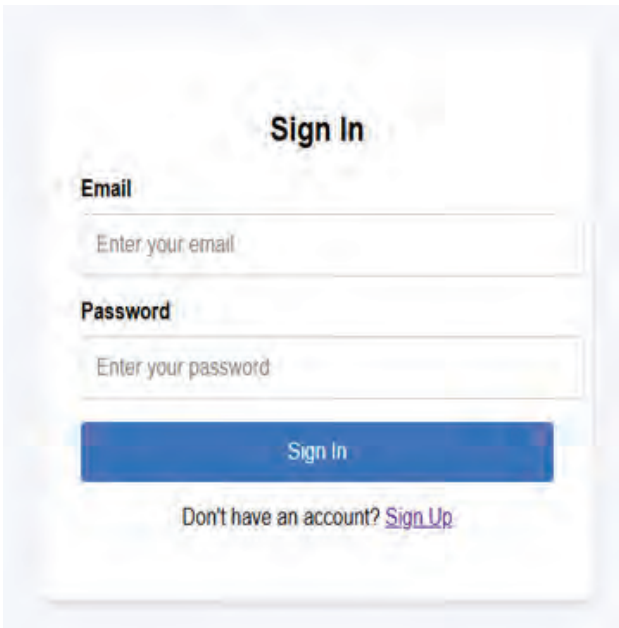


Fig. 5: Sign-in Functionality



Fig 6: Terrian Area Classification

Figures

The above figures describe a system workflow beginning with a user interface for sign-in or sign-up, where users input their credentials to access the platform. After logging in, users provide coordinates (latitude and longitude) to extract images from GEE and perform data preprocessing. Factor analysis takes into account terrain, elevation, river basins, agricultural land, and weather to ensure a safe and secure route. Finally, the system performs a safety check and provides route recommendations or optimization based on the analysis.

CONCLUSIONS

The proposed system for safe and secure route finding in terrain areas addresses the significant challenges of navigating rough terrains by leveraging advanced “satellite imagery and digital elevation models”. At its core, “the system integrates the Efficient Vision Transformer (VIT-M2) model for terrain classification, achieving an impressive accuracy of 98.76%”. This high accuracy outperforms other models in terrain analysis, ensuring precise identification of terrain types. Additionally, the system employs optimized route calculation algorithms that account for critical factors such as slope, elevation, and real-time weather conditions. This approach minimizes exposure to high-risk zones, significantly enhancing safety during navigation. The solution demonstrates strong potential in real-world applications like disaster response, military operations, and off-road expeditions, where secure navigation is vital. This research makes a notable contribution to the field of terrain-based navigation by combining advanced machine-learning techniques with satellite imaging for route optimization. The proposed methodology not only ensures safety but also provides a scalable and efficient framework suitable for practical implementation. Future enhancements could further strengthen the system by incorporating dynamic weather data to improve real-time decision-making, enabling route visualization for better planning in complex terrains, and integrating multi-sensor data from various satellite sources to increase reliability and accuracy. These advancements would make the solution even more robust, offering reliable navigation tools for emergency management, secure exploration, and other critical applications in challenging environments.

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Real Time Face Spoofing Detection using Machine Learning

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ABSTRACT

With proliferation in the use of Face Authentication systems in various government and financial institutions that involve software which make use of facial recognition technologies for the purpose of authentication to carry out processes like EKYC document verification, bank transactions and authentication. It is found that such systems are prone to spoofing attacks, contributing to fraud and impersonation attempts in such systems. The previously introduced solutions involve the use of Neural Networks to overcome this issue. We propose a hybrid architecture that makes use of CNN based architectures namely MobileNet V3 and XceptionNet for the purpose of detecting spoof attacks as well as DeepFake attacks. We also conduct EXIF metadata checks on image files to detect Virtual Webcam impersonation attacks to ensure secure authentication in face recognition-based authentication systems.

KEYWORDS : *Face authentication, Artificial intelligence, Convolutional neural network, DeepFake, Anti DeepFake, Antispoofing, Spoof detection.*

INTRODUCTION

Face-based authentication systems are biometric security mechanisms that use facial features to carry out authentication. These systems work by capturing an image of subject using a camera, processing it through computer vision algorithms, and comparing it against a stored database of authenticated facial templates. The process generally involves detection of subject's face, extracting features, and matching the results.

The origin of facial recognition system (FRS) can be traced back to early research in computer vision during the 1960s, where studies focused on the recognition of geometric facial structures [1]. With the bloom of machine learning and deep learning algorithms, the field experienced significant advancements, particularly with the introduction of convolutional neural networks (CNN). CNN-based systems are capable of identifying intricate patterns in facial features such as pupillary distance, shape of nose, jawline contours making modern systems highly accurate and reliable.

These algorithms are widely used in many applications involving security, verification and authentication. Some examples being Apple Face ID technology [2] in which a 3D map of user's face is used captured by depth sensing camera, in online payment services in China like Alipay and WeChat Pay [3], Airport security checks like CLEAR, immigration clearance and boarding checks [4], in schools and universities to track attendance, one example being IIT Delhi's biometric attendance system. Furthermore, retail outlets in China use Smile to Pay payment system which utilizes facial recognition to process payments.

From aforementioned statements, it is understood that facial recognition is widely used, use cases being too many to name. However these systems can be circumvented by exploring exploits in implementation, algorithm like Face Spoofing, DeepFake injections and virtual camera misuse.

Face Spoofing

Spoofing attacks in face recognition involve circumvention of face recognition check by presenting fake or manipulated

inputs such as printed photographs, digital image, videos or 3D mask of users face. [5]



Fig. 1: Face Spoofing attempts

Researchers in the Black Hat community managed to demonstrate the vulnerability of face authentication systems by bypassing laptop system FRPs through face presentation attacks. This study involved researchers trying to bypass Toshiba, Asus and Lenovo laptop which would allow unauthorized access to laptop. [6]

Spoofing attacks are classified as 2D spoofing and 3D spoofing. 2D spoofing involves photo attack and video attack. Whereas 3D attack involves bypassing system by the use of 3D printed silicon mask. [7]

DeepFake

A DeepFake, graphic media in particular, involves creation of morphed media by using deep learning techniques like Neural Networks to create hyper realistic media like images and videos. The process involves target video and candidate video, whereas the DeepFake features are used from candidate video over on target video. It uses encoders to produce a latent representation of the features of the input image while a decoder reconstructs the latent features back into image. [8]

The generated DeepFake content can result in devastating ramifications and may possibly result in political, public and social unrest. One example of such is a video circulating on Social Media in Mar 2022 of Ukraine's Prime Minister Volodymyr Zelenski advising pro Ukraine militant forces to give up arms [9]. Similarly there can be misuse through fabricated erotic content in other domains like conference calls and online meetings.

A programmer used DeepFake technology on webcam and impersonated Elon Musk joining wrong online meetings [10]. As a result of blooming advances in DeepFake hyperrealism and ease of access, incidents involving impersonation are increasingly becoming frequent in online chatrooms, conferences.

Virtual Camera

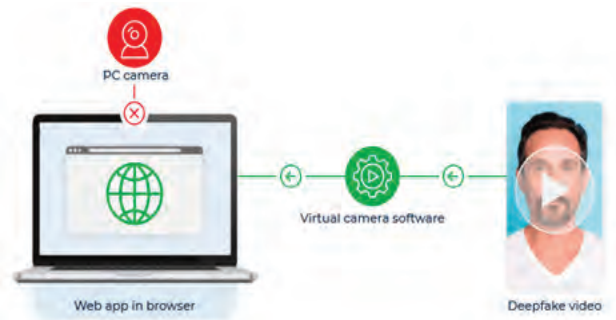


Fig. 2 Feed injection attack [11]

A virtual camera attack involves injection of a video feed in web camera feed. Such attacks can be carried out for the purpose of impersonation, to circumvent face authentication systems and other malicious purpose [12].

An example of this being used could be Omegle chatrooms, online conference meetings like Zoom. Web cam feed can be injected by use of virtual camera software such as OBS, ManyCam, AlterCam to name a few.

With all above attacks in consideration, Face Authentication becomes unreliable and insecure. The currently offered and publicly available non commercial solutions merely solve the problem by using a spoof detection classifier as a solution.

As a result, we propose a hybrid approach that solves the 3 prominent issues.

LITERATURE REVIEW

Anti-Spoofing Systems

Researchers have explored various methods to enhance the security of biometric to counter spoofing attacks. A comprehensive study categorizes face anti-spoofing techniques into hardware based and software based methods. Hardware based approaches often require specialized equipment, while software-based methods are divided further into static and dynamic techniques. Static methods involve analysis of texture patterns, whereas dynamic methods assess motion or liveness cues.

In a survey, the limitations of current face anti-spoofing methods were highlighted, particularly concerning real world conditions and evolving nature of spoofing techniques. The study emphasizes a need for more robust and adaptable solutions to address these challenges. Classifiers, Neural Networks to be precise are frequently used to predict the classes and properties inherent in datasets and can be used across multiple disciplines, an example being medical diagnostics. A research involved removal of noise from brain MRI and to detect and classify brain tumors by the use of CNN, SVM from MRI scans. [5],[19].

Attendance Systems

The evolution of attendance systems has seen the integration of various technologies to improve accuracy and efficiency.

Four AI and ML researchers from India from an engineering institute in Hyderabad proposed a ResNet 50 architecture based spoof detection enabled detection system, achieving an accuracy of 95.85%. [13]

A team of Indonesian created an anti-spoofing based attendance system achieving an accuracy of 98.36% by using MobileNet V2 CNN architecture. [14]

Another research involved research students from Andhra Pradesh who proposed a Haar cade algorithm and MobileNet system, achieving an accuracy of 98.62%. [15]

In another study, researchers from Pakistan proposed the use of MobileNet V2 architecture for Spoof detection, achieving an accuracy of 98.6%. [16]

METHODOLOGY

We've proposed the following system

Proposed System

The system proposed by us makes of two neural network architecture namely MobileNet V3 Improved and XceptionNet for detecting spoof attacks and DeepFake attacks.

Furthermore, we maintain checks in the system for metadata of camera feed to detect for possible video injection attacks.

This system will be hosted on a React based web environment, with PostgreSQL database and Express and Node for backend.

Tensorflow.js will be used for client side processing to improve server performance with double ended AES256 encryption.

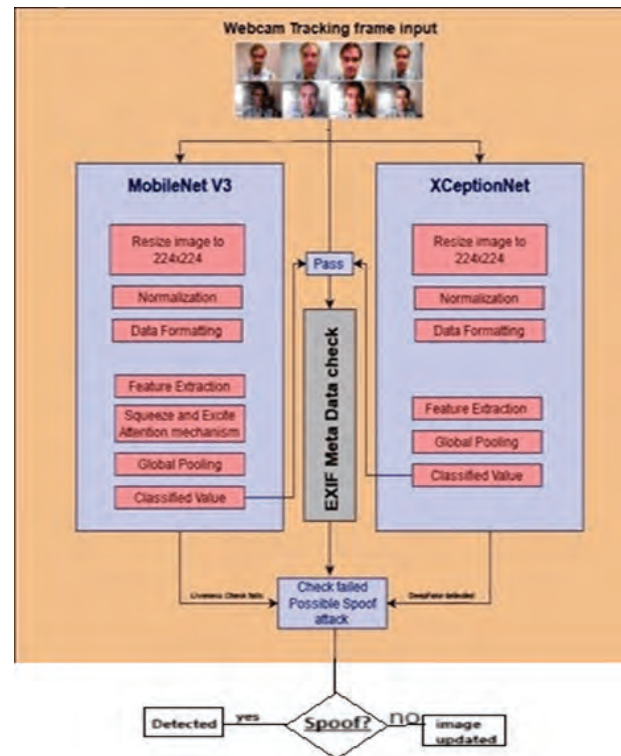


Fig. 3: Proposed System Architecture

Experimental Setup

The setup consists of three main components: the development environment, libraries and tools, and the deployment environment.

Development Environment

Platform: Kaggle Python Notebook (GPU: Nvidia P100)

Libraries and Tools

The libraries and tools and frameworks involved are as follows:

Tensorflow.js, React.js, Matplotlib, OpenCV, Pytorch, Sklearn, Tensorflow, Flask, Express.js

Dataset Collection

Existing datasets lack low-light conditions, so we created a dataset covering various ages and lighting scenarios to account for poor camera quality. Additionally, multiple publicly available datasets were combined to enhance diversity in conditions and camera quality.

Sr No	Name	Author	Source	Summary
1	NUAAAA	X.Tan, Y.Li, J.Liu and L.Jiang	NUAAAA dataset src [17]	Subjects: 16 Train: 1743 real / 1748 fake Test: 3362 real / 5761 fake
2	Replay Attack	Ivana Chingovska, Andre Anjos and S´ebastien Marcel	Replay Attack Dataset src [18]	Subjects: 50 1300 video clips of 9 sec.
3	Personally Collected	Anant Chavan, Sankalp Borse, Ayush Bhavsar, Nitish Soni	Custom synthesized	Subjects: 100 25 real and 25 spoof each

The collected dataset is then processed as 299x299 images, its segmented maps are generated and fed into classifier for feature learning.

The dataset is synthesized with the help of 100 live subjects, each subject has 25 real and 25 spoof pictures. This is used in conjunction with NUAAAA dataset which has 16 subjects with around 12,614 entries.



Fig. 4: Collected dataset

Model Training

The MobileNet V3 and XceptionNet models will be trained using the TensorFlow/Keras framework. Transfer learning will be employed by using pre-trained weights on ImageNet, followed by fine-tuning on the collected datasets to enhance feature extraction for anti-spoofing. The dataset will be divided into training, validation,

and testing sets, usually in a 70:20:10 ratio. To mitigate overfitting, techniques such as early stopping and dropout regularization will be implemented during training. The models optimization will involve Adam optimizer, loss function being the categorical cross-entropy.

Model testing and validation

Model's performance will be monitored by the use of validation set during model validation during training. After training, the testing set will be used to evaluate the models' final performance based on metrics such as accuracy, precision, recall, and F1-score. Cross-validation will also be conducted to ensure generalization and to confirm the models' robustness across different subsets of the data.

Prevention of Virtual Webcam

To address virtual webcam attacks, multiple techniques will be employed. EXIF metadata analysis will be used to verify the authenticity of captured images, checking for details like camera make, timestamps, and geo-tags. Frequency analysis will be applied to detect inconsistencies in image noise patterns, which are often a telltale sign of digital manipulation. Frame rate and resolution analysis will be performed to detect anomalies commonly found in virtual streams.

Deployment

The trained models will be deployed on a web application using TensorFlow.js for real-time inference directly in the browser. The web application will have a React-based frontend, ensuring an intuitive and responsive user interface. The backend, built using Express and Node.js, will manage API requests and facilitate communication with the database. PostgreSQL will serve as the database, storing user information, detection logs, and EXIF metadata for reference and auditing purposes. This architecture ensures scalability, efficient processing, and a seamless user experience.

RESULTS AND DISCUSSION

Performance Parameters

The proposed anti-spoofing system demonstrated exceptional performance in detecting spoofed inputs. The MobileNet V3 architecture achieved an accuracy of 99% on the test dataset, showcasing its efficiency and lightweight nature for real-time applications. Meanwhile, the XceptionNet architecture outperformed slightly,

achieving an accuracy of 98.2%, owing to its deeper feature extraction capabilities.

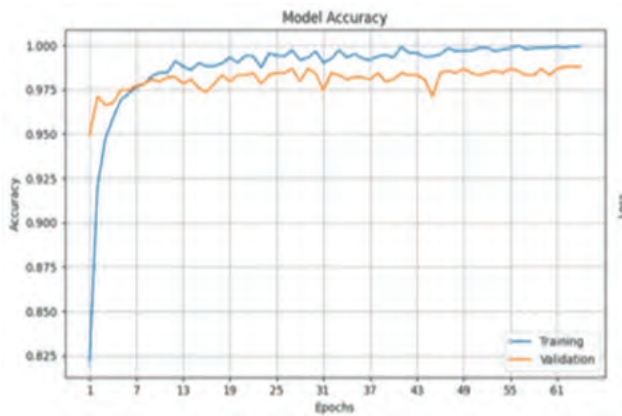


Fig. 5: Accuracy graph of MobileNet V3 architecture

Our proposed solution and classifier improves upon previously trained classifiers like ResNet 50 based NUAAAA dataset classifier having accuracy of 95.85% [13].

A MobileNet V2 classifier trained on Github and Real time dataset with an accuracy of 98.62% [15]. Furthermore, we also achieved better accuracy compared to a classifier trained on MobileNet V2, dataset being LCC FASD having an accuracy of 98.6% [16]

Table 1: Comparison between previous systems

Sr No	Classifier	Dataset	Accuracy
1	ResNet50	NUAAAA	95.85%
2	MobileNet V2	Github and Real Time	98.62%
3	MobileNet V2	LCC FASD	98.6%
4	MobileNet V3 Improved	NUAAAA + Replay Attack + Personal Dataset	99%

The system proved to be robust against different kinds of spoofing attacks, including printed photo attacks, video replays, and digital manipulations. In the prevention of virtual webcam attacks, techniques such as EXIF metadata analysis, noise pattern detection, and liveness detection significantly contributed to the system's reliability. These measures successfully detected virtual streams and prevented spoofing attempts in real-world scenarios.

Furthermore, deploying the models on a web interface enabled seamless real-time inference with minimal latency. The integration of PostgreSQL ensured secure storage and

retrieval of detection logs, enhancing the overall system's robustness and auditability.

Table 2: Model Performance Parameters

Classifier	Dataset	Accuracy	Precision	Recall	Support	F1 Score
MobileNet V3 Improved	NUAA Replay Attack Personally Synthesized	99%	99.2%	99.23%	99%	99.12%
XceptionNet	FaceForensics++	98.2%	97.9%	97.1%	96.8%	98.25%

Detection logs on demonstration environment. Here the user Sankalp has requested to update their profile picture through their web cam feed. The update fails if a DeepFake attack, spoof attack or video injection attack gets detected.

Model Training

Learning rate of 0.0001 followed for all instances.

Table 3: Accuracy and epoch table

Epochs	Accuracy
8	95%
16	96%
32	96%
64	99%

CONCLUSIONS

Our proposed system successfully enables a robust and reliable anti-spoofing based face authentication leveraging MobileNet V3 and XceptionNet architectures. The models achieved accuracies of 97.2% and 98%, respectively, highlighting their effectiveness in detecting spoofing attacks. By employing techniques such as EXIF metadata analysis and liveness detection, the system exhibited

resilience against various attacks, including virtual webcam attacks.

Most solutions of virtual webcam are commercial and with this research, it is also conclusive that prevention of video injection attacks is difficult due to the injection attack posing as a USB in form of driver.

This hybrid approach can be further delivered in the form of adhoc utilizable API service.

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Optimizing Blockchain Mining for Fairness and Efficiency in Decentralized Networks

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ABSTRACT

The growth of the digital economy has made data a key asset bringing new issues about its control and management. Blockchain technology offers a decentralized system that allows for clear operations and good use of data, along with fair management tools. Bitcoin kicked off blockchain in 2008, and since then, developers have put this groundbreaking tech to work in healthcare, IoT, and supply chain systems. Blockchain mining faces two big hurdles: its power needs at scale and its tendency to centralize. This paper looks at ways to improve blockchain mining by studying dynamic difficulty adjustment methods, mixed consensus systems, and spread-out reward structures to achieve fair and better operations. The paper weighs different consensus models like Proof of Space and Proof of Burn checking how energy-efficient and scalable they are. The goal is to come up with ways that encourage fair mining while pushing blockchain networks to create lasting blockchain settings that include everyone.

KEYWORDS : *Blockchain technology, Consensus algorithm, Proof of work (PoW), Proof of stake (PoS), Delegated-Proof of stake (DPoS), Practical byzantine fault tolerance (PBFT), Raft, Blockchain architecture.*

INTRODUCTION

In today's economy, data has become one of the most valuable assets. However, there is still no clear consensus on who truly owns this data. Blockchain technology offers a promising solution by providing a decentralized and fair way to manage and utilize data efficiently. Often described as a "decentralized ledger," blockchain enables multiple participants to interact with data without relying on a central authority, ensuring transparency and fairness. Blockchain is a revolutionary technology that allows tracking of information along with its senders and recipients over the internet. These fundamental principles form the backbone of blockchain technology. In 2008, Satoshi Nakamoto introduced the concept through his paper, "Bitcoin: A Peer-to-Peer Electronic Cash System," which laid the foundation for digital currency transactions. Originally designed to record Bitcoin transactions, blockchain eliminates intermediaries, reduces fraud risks, speeds up transactions, and lowers costs, fundamentally disrupting traditional financial and business processes.

Blockchain is a highly secure and tamper-resistant digital ledger that typically operates without a central governing

body. It enables multiple users to record transactions in a shared database, ensuring immutability and transparency. Imagine blockchain as a digital record book where transactions are stored in blocks, each securely linked to the previous one, making it extremely difficult to alter past records. This security is maintained through a validation and consensus mechanism among users. As more transactions are added, modifying previous entries becomes increasingly challenging. Since copies of the ledger are distributed across a network of computers, any discrepancies are automatically corrected based on pre-defined rules.

Beyond financial transactions, blockchain facilitates the exchange of assets such as labor, votes, property, goods, and digital currencies through a transparent and decentralized system. Acting as a secure and distributed data structure, blockchain records transactions across a network, with each entry being timestamped and permanently stored once added to a block.

LITERATURE REVIEW

The literature review analyzes multiple obstacles in the

progress and development of the blockchain consensus mechanism and improves the performance of it over many areas.

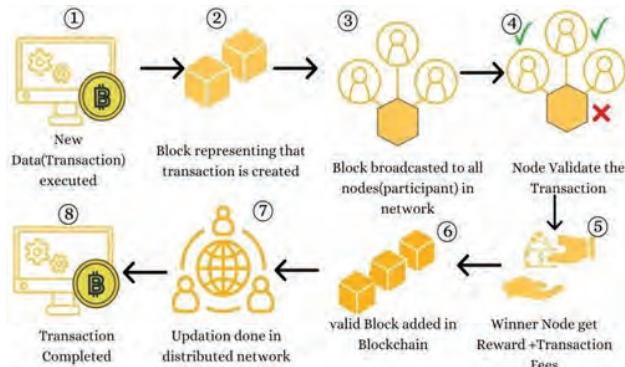


Fig. 1. Blockchain Working

Bhutta et al. (2021) present an updated and complete survey of the blockchain technology which includes its history, architecture, development frameworks, and completely new concepts and challenges about security. In contrast to other surveys, this one examines consensus algorithms and other security threats and cryptographic techniques alongside some new applications. It further assesses the existing frameworks and outlines the challenges of the future aiding the research community, academics, and business practitioners to comprehend the global status of blockchain technology so that they can exploit for future development opportunities [43].

In their work, Haung et al. (2023) implement an approach featuring an improved DPoS-PBFT hybrid model with IoT optimized software defined blockchains. This approach proves highly effective as there is a visible consensus mechanism with higher performance and success rate, lower latency, and even better resource efficiency compared to older consensus mechanisms [34].

Yang et al. (2023) make a new proposal regarding the Delegated Proof of Stake (DPoS) consensus, encouraging community member participation in the development. Their proposal also includes the CD-DPoS algorithm whereby the PageRank algorithm[35]

In the context of existing literature, Shannan Liu and others (2023) worked out a PBFT algorithm particularly adapted for traceability within the pharmaceutical industry. Their implementation of PBFT is done through a modification of the consensus protocol using a credit model for dynamic node status changes and grouped node decision consensus. The experiments showed lower transaction latency,

improved throughput, and better fault tolerance, making this traceability system more effective compared to other solutions [36].

Focussing on healthcare applications, Hegde and Maddikunta (2023) design around the secure lightweight PBFT blockchain model augmented by EigenTrust and Verifiable Random Function (VRF). Simulation results indicated that their algorithm achieved higher throughput than traditional PBFT while reducing latency and faulty nodes which improve its usability for secure healthcare blockchain solutions [37].

Qian Hu et al. (2021) presented Reputation- DPoS, an advanced version of the Delegated Proof of Stake that aims to resolve the problems of abusing nodes and low participation from voters in blockchain systems. ‘Reputation- DPoS,’ employs a combination of trusted state classifications with an incentive mechanism based on reputation to increase the level of engagement from nodes, thereby improving security and efficiency [38].

Saad et al. (2021) have proposed e-PoS, which is an improved version of Proof of Stake and aims to improve energy efficiency, fairness, and decentralization. This protocol utilizes blind block auction policies for reward distribution and also uses PBFT for decentralization, security, and fairness, as was described in their simulations [40].

Finally, Li et al. (2020) have developed Robust Proof of Stake (RPoS) which contributes to the development of blockchain economics. This protocol uses a dynamic stamp-age baseline, computations of stakes, and a system that mitigates double contention attacks by nodes. The results show improved attack tolerance and higher transaction processing speeds (TPS) [41].

CHALLENGES IN BLOCKC MINING

One of the most practical issues of blockchain mining stems from its energy requirement, particularly in Proof of Work (PoW). The process of mining leads to the consumption of enormous amounts of electricity, thus, increasing the environmental and expenditure apprehension. Imbalances of power are posed by the wealthier participants in Proof of Stake (PoS) models, thus, triggering centralization risks which prevent smaller stakeholders from efficiently participating in the consensus mechanism. Moreover, there are significant entry barriers in this regard, since mining hardware is very costly. Large scale firms control the majority of the PoW networks, preventing individual

miners from being competitive, hence, further centralizing mining power. Many security vulnerabilities exist that can cause damage to the system. Selfish mining, 51 percent attacks, or the existence of mining cartels enables malicious actors to gain tremendous power over the system. Irrespective of the damage being done, blockchain has its trust compromised, transaction controls manipulated, and system integrity altered. The creation of new consensus algorithms/report, energy-efficient mining methods, and advanced forms of decentralized governance are some of the improvements that would ensure a blockchain system that is both secure and sustainable.



Fig. 2: Challenges in block mining

PROPOSED METHODOLOGIES

For blockchain mining to be fair and performant, it is necessary to put into practice strategies addressing both equitable participation and network performance. Here's an overview of the key approaches:

Strategies for a more equitable mining approach

Dynamic Difficulty Adjustment Mechanisms

These mechanisms guarantee that mining opens up to subjects with different hardware power by dynamically scaling the mining difficulty according to network state. This cookie prevents high computational power nodes from dominating the web, allowing all miners to participate fairly.

Fair Reward Distribution Models

Proportional mining rewards contribute to reducing centralization by assigning rewards in proportion to the contribution and not to arbitrary computational power. This will help in broader participation and making it much less likely for a small number of powerful entities to "own" the mining rewards.

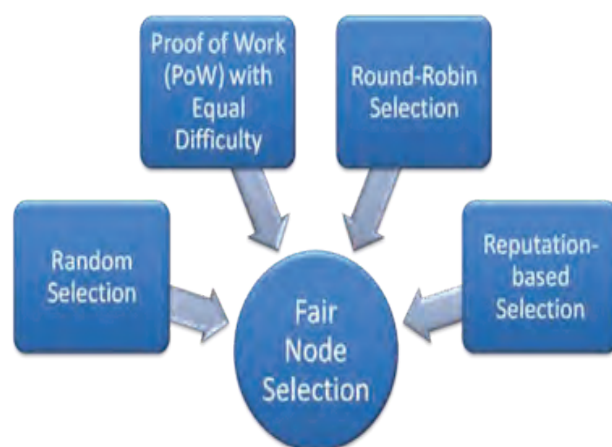


Fig. 3 Fair node section approaches

Hybrid Consensus Models (PoW + PoS)

A hybrid method that integrates Proof of Work (PoW) and Proof of Stake (PoS) addresses security, decentralization, and efficiency of blockchain. PoW allows decentralization by computational effort, PoS allows it by negating energy cost and the potential for concentration of mining power.

Incentivizing Decentralized Participation

By designing utility reward structures that encourage smaller miners and individual participants, however, blockchain networks can remain free of the risk of runaway mining power accumulation. Resistive base and passive beam curvature assembly reduce hardware needs and innovation applications of a new mining technique (e.g., Proof of Space) promise more decentralized participation and ease the possibility of centralization and network stability

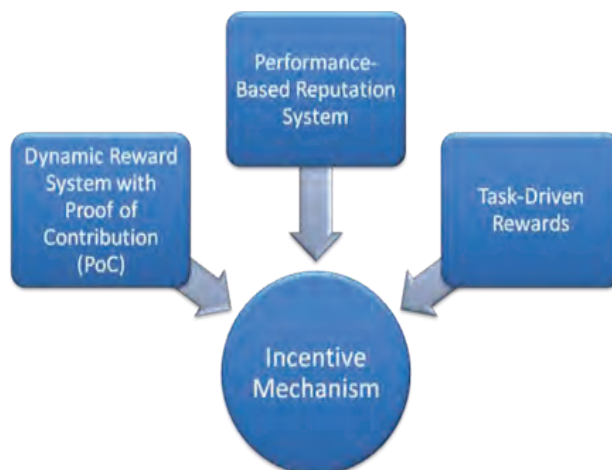


Fig. 4: Incentive mechanism approach

Enhancing Blockchain Network Efficiency

Faster Transaction Validation and Block Propagation

The process of optimizing blockchain networks is based on increasing the rate at which transactions are being certified and blocks are disseminated by the network [7]. This saves congestion, minimizes latency, and enables better, faster trade processing, making for a more efficient network from bottom to top.

Alternative Consensus Mechanisms (Proof of Space, Proof of Burn)

Alternative consensus models, such as Proof of Space and Proof of Burn, offer energy-efficient means of securing the blockchain, all the while ensuring a high degree of security. These techniques use significantly less computational cost than Proof of Work (PoW) and thus contribute to the reduction of environmental factors while maintaining the validity of the blockchain.

Scalability Solutions (Sharding and Sidechains)

Sharding and side chains allow blockchains to scale better, by processing transactions in parallel and/or offloading some transactions to dedicated chains. These solutions contribute to the ability to process a greater number of transactions, such as relieving congestion and enhancing performance in the blockchain as a whole.

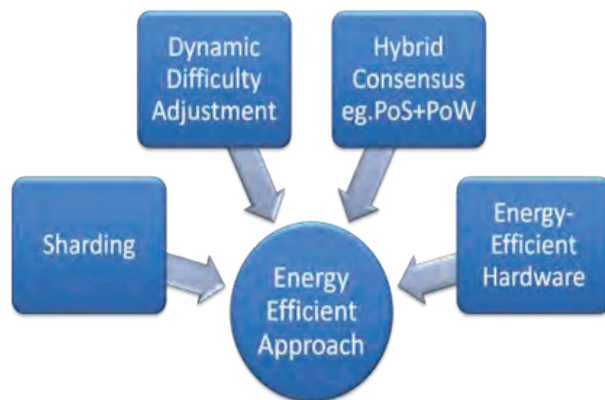


Fig. 5. Energy Efficient Approaches

CONCLUSIONS

The optimization of blockchain mining is extremely important for the sustainable development of pervasive networks, especially for fairness and performance issues. With the further development of blockchain technology, it is crucial to take dynamic difficulty adjustment

methods and equitable reward distribution policies into consideration to encourage fair participation. Hybrid consensus architectures, which integrate Proof of Work (PoW) and Proof of Stake (PoS), produce a compromise between security and scalability, and are respectively counterposed to consensus mechanisms of Proof of Space and Proof of Burn, both of which offer energy-saving alternatives. Support for decentralized participation and the prevention of a miner power concentration via incentivized reward mechanisms further enhances the blockchain ecosystem. By combination of these strategies, not only blockchain network performances will be enhanced, but also equitable, sustainable and secure decentralized world will be formed. With blockchain set to continue to disrupt existing systems, these developments will be particularly important in helping to build trust, transparency, and widespread adoption.

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Next-Gen Threat Detection: Leveraging Federated Learning for Malicious URL Identification

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ABSTRACT

Malicious URLs are a serious cybersecurity risk that are commonly used in malware and phishing attacks. The continuously changing and opaque nature of these threats frequently makes it difficult for traditional detection methods, such as centralized blacklists, to keep up. These technologies also pose serious privacy problems for users. To overcome these barriers, we have established a federated-learning based scheme for malicious URL detection that enables decentralized model training to increase user privacy and detection capabilities. This framework conducts real-time analyses of URL structures, lexical features, and blacklist references to identify potential threats effectively. Leveraging a dataset of 5,000 URLs sourced from reputable platforms like URLhaus and PhishTank, our approach demonstrates superior performance compared to existing methods such as PDRCNN and URLNet, particularly regarding privacy preservation. This research highlights the promise of federated learning in delivering robust solutions for real-time malicious URL detection while maintaining user confidentiality.

KEYWORDS : URL detection, Federated learning, Malware, Machine learning, Extracting feature, Privacy, Preservation, Blacklist techniques, URL Classification.

INTRODUCTION

In the age of the internet, maintaining cybersecurity is critical to protect assets from cyber-attacks. Malicious URLs are often used as instruments in phishing and malware attacks, misleading users and putting sensitive data at risk. Traditional detection techniques like blacklists and signature-based systems tend to be ineffective in combating emerging and obfuscated threats and create privacy issues with centralized data processing.

Federated Learning (FL) offers a privacy-aware solution by enabling devices to collectively train models without sharing raw data. This work proposes a real-time system for malicious URL detection based on FL, which scans URL structures, lexical features, and reference blacklists. It focuses on protecting user privacy, enhances detection

efficiency, and evades the disadvantages of conventional techniques, leading to a scalable and adaptive system.

The increasing sophistication of cyber-attacks, especially via malicious URLs, requires smart detection mechanisms. Conventional methods tend to miss new and hidden links, exposing users to threats. The rise in mobile usage and QR codes has also increased attack surfaces. This project responds to the requirement for an adaptive, real-time system that reduces false positives, improves detection rates, and enhances cybersecurity.

The destination of this project is to break a federated eruditeness-based system to name malicious uniform resource locator with a focus on heighten signal detection accuracy and effectiveness. The system is designed to provide high detection rates with minimal false positives

and negatives. The system will analyse URLs based on 42 predefined characteristics, such as blacklist status and lexical features, and assign priority coefficients to highlight vital factors for enhanced efficiency. Through the integration of feature evaluation methods, the system will be dynamic in addressing emerging threats to maintain effectiveness. The system is also built for the effective management of large-scale datasets, facilitating real-world scalability and strong cybersecurity practices.

LITERATURE REVIEW

As the digital landscape continues to evolve, cybersecurity threats are growing in both frequency and sophistication. One of the most dominant and dangerous methods utilized by cybercriminals today is the deployment of malicious URLs, which are oft used for phishing, malware distribution, and early cyberattacks aimed at compromising sensitive data [2]. These malicious URLs are often designed to mimic legitimate websites or conceal harmful payloads, making them difficult to detect using traditional methods [6]. With the growing reliance on online chopine and the increasing number of exploiters get at the cyberspace through wandering devices and personal calculator, the potential drop for cyber-attacks has enlarge significantly. Both individuals and organizations face severe risks from these malicious activities, necessitating the development of advanced detection systems that can address these evolving threats in real time [4].

Traditional methods of URL detection, such as blacklists, though useful, are increasingly leaven to be inadequate due to their inability to hold open up with the perpetually evolving nature of cyber threats [5]. Blacklists rely on previously identified malicious URLs, but cybercriminals are continuously generating new URLs and using sophisticated obfuscation techniques to bypass these defenses [3]. Moreover, existing centralized detection systems, while capable of leveraging machine learning algorithms for improved accuracy, often come at the cost of user privacy. These systems require extensive data collection, raising concerns about data misuse, privacy breaches, and compliance with stringent privacy regulations [8]. Additionally, centralized methods frequently suffer from high latency, limited scalability, and frequent false positives, making them less effective for real-time, large-scale detection of novel threats [2].

This decentralized framework allows for enhanced privacy and data security, as sensible entropy remains

on local gimmick, while only model updates are shared with the central server. Federated learning makes sure the system can learn from many spread-out data sources without putting privacy at risk. This makes it a good fit for use in cybersecurity [9]. This not only reduces the risk of data breaches but also helps organizations comply with increasingly stringent data privacy regulations. As a result, federated learning has the potential to cause a revolution in how we spot harmful URLs. It strikes a balance between performance in real time, the ability to scale up, and keeping things private [4]. By enabling devices to collaboratively train models without directly accessing each other's data, federated learning helps improve the detection of novel cyber threats while preserving user privacy. The decentralized nature of federated learning also makes it more resilient to certain types of attacks, such as adversarial attacks, which are more prevalent in centralized systems [5]. In this context, real-time data analysis becomes essential for identifying and mitigating cyber threats before they can cause significant harm.

The framework suggested in this paper uses federated learning to create a productive instant system to spot harmful URLs. By analyzing real-time features such as URL structures, lexical characteristics, and blacklist references, the system is designed to detect malicious URLs dynamically. Feature extraction techniques play a crucial role in identifying key patterns that distinguish malicious URLs from benign ones. The framework ensures that all these processes occur in real time, enabling the system to respond to threats immediately [7]. Furthermore, the system offers flexibility, allowing for manual interventions when necessary, such as during phishing attacks or malware outbreaks, where immediate action is required to prevent further damage [2].

The system uses distributed data to train models that predict potential cyber threats, ensuring that users are protected against the latest forms of attacks [9]. By balancing scalability and performance, this framework has the potential to be deployed across large networks, offering comprehensive protection while maintaining user privacy. As cybersecurity threats continue to evolve, such systems will become increasingly vital in safeguarding online platforms and ensuring data security.

This article presents a wide federal learning framework for malicious URL detection, adapted privacy, and scalability.

METHODOLOGY

System Design Architecture

The system is designed to handle real-time malicious URL detection through three phases: identification, classification, and evaluation. URLs are input manually or from a dataset, processed through feature extraction techniques, and classified using a machine learning model trained on historical data. The system dynamically adjusts detection based on the lexical characteristics of the URL and its appearance on known blacklists.

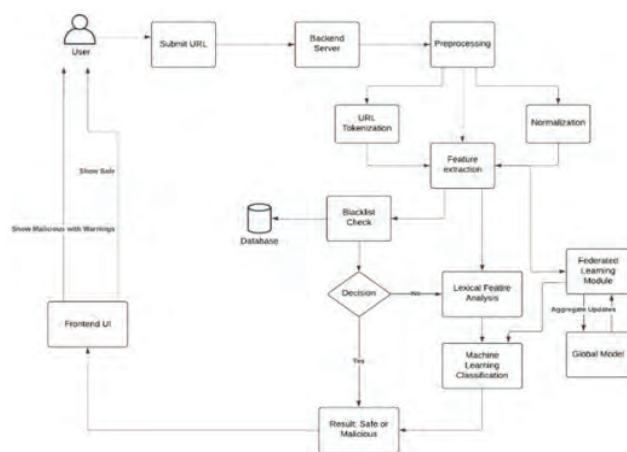


Fig. 1: System Architecture

Identification Phase

In this phase, the input URLs undergo initial processing to detect obfuscation techniques commonly used in malicious URLs, such as URL shortening, domain misdirection, and keyword obfuscation. The identification algorithm checks for patterns like:

- URL shortening (URLs disguised as legitimate links)
- Domain-based obfuscation (using similar-looking domains)
- Keyword-based obfuscation (injecting misleading keywords) Complex URL structures This phase detects, and resolves shortened or obfuscated URLs by analysing the redirection chain and isolating the final destination of the URL. The original URL is extracted and sent to the feature classification phase for deeper analysis.

Feature Classification Phase

After identification, the URL is subjected to two primary feature extraction methods:

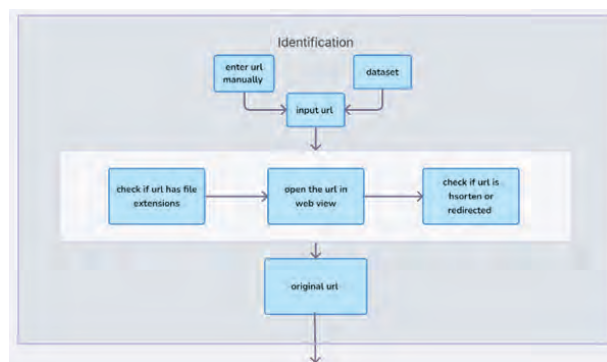


Fig. 2: Identification Phase

- Blacklist-Based Detection: The URL is checked in opposition to recognised blacklists of malicious URLs. If the URL suits an access inside the blacklist, it is classified as malicious.
- Lexical Feature Extraction: For the URL not available in blacklists, the literal analysis for testing of URL is used, where includes.:
 - a. URL length
 - b. Number of sub-domains
 - c. Special characters or numbers used
 - d. Suspicious keywords in the URL path

Once these features are extracted, a priority coefficient is assigned to each based on its likelihood of indicating malicious intent.

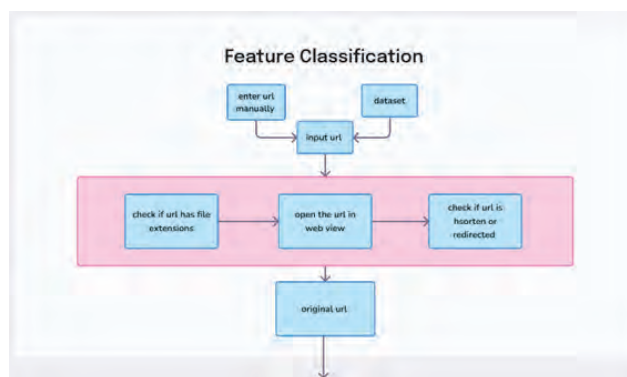


Fig. 3: Feature Classification Phase

Feature Evaluation Phase

In this phase, the system evaluates the relevance and contribution of each feature to the overall classification decision. Priority coefficients are applied to determine the weight of each feature in the final risk score calculation.

The comparison of score can be determined whether URL is safe or malicious. If the score passes the threshold, the URL is flagged as malicious. If it falls below the threshold, the URL is considered benign; this phase ensures that only the most significant features contribute to the final classification, thereby optimizing the accuracy of the model.

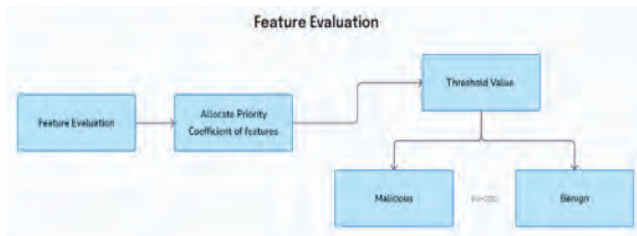


Fig. 4: Feature Evaluation Phase

Model Training

The framework leverages machine learning algorithms such as Random Forest to classify URLs based on features extracted previously. The model is learned on a set containing benign and malignant URL samples, using the historical data about phishing websites and malicious URLs repositories. As new URLs are processed, the model continues to refine its classification through feedback loops and further training.

Testing and Evaluation

Before deployment, the system undergoes rigorous testing with a variety of datasets to ensure its effectiveness. Simulation tools are used to validate the system's behaviour under different scenarios. Testing ensures that the features are extracted accurately and robustness of the model. The final system is validated against real-world data to ensure high reliability in detecting malicious URLs.

SPECIFICATIONS

- Federated Learning framework enables decentralized model training to preserve user privacy.
- Real-time detection identifies malicious URLs with minimal latency.
- Priority coefficients assign weights to features to improve detection accuracy.
- Privacy preservation ensures compliance with data protection regulations.
- The system is scalable for large datasets and multiple clients.

- Low-latency processing delivers immediate user feedback.
- A user-friendly interface is designed for ease of use by all users.
- Benchmarking results show better performance compared to PDRCNN and URLNet.
- The system handles large-scale datasets efficiently.
- Adheres to cybersecurity standards for data handling and system architecture.

RESULTS

The suggested malicious URL detector showed excellent performance in detection and classification of malicious web addresses. It was tested on a large dataset obtained from trusted sources like URLhaus and PhishTank to provide a large spread of threats from the real world. The new system shines when analyzing things and it also knows more correctly which cases get the call to action to do special handling compared to systems that use blacklists and heuristics alone. Using a suite of different methods of machine learning work, this system really excels at processing different aspects of URLs and it does much better at drawing lines between unsafe and safe URLs.

Findings are very clear that the new framework we've introduced is good and very adaptable for catching bad URLs. Through the incorporation of priority coefficients and a more advanced feature evaluation approach, the system can effectively improve cybersecurity defense, providing a cost-effective way to detect evolving phishing and malware threats.

CONCLUSIONS

The Real-Time Malicious URL Detection Platform Using Federated Learning enhances cybersecurity by identifying harmful URLs in real-time while ensuring user privacy. The framework assigns priority coefficients to critical features, ensuring that the detection algorithm focuses on the most relevant indicators of potential threats, thereby enhancing sensitivity and precision. Additionally, an intuitive user interface facilitates seamless interaction for cybersecurity professionals, while continuous monitoring and reporting provide actionable insights to adapt to evolving cyber threats. Overall, such an innovative approach not only enhances the detection of malicious URLs but also aids the larger field of cyber security by providing an effective means to fight off new and emerging threats.

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Tone Craft: A Professional and Friendly Tone Enhancer

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ABSTRACT

Effective communication relies not only on content but also on tone, which can significantly impact clarity, professionalism, and engagement. ToneCraft is a tone conversion and text style transfer framework designed to seamlessly transform text between professional and friendly tones while preserving the original meaning. Utilizing BERT for classification and T5 for text transformation, ToneCraft ensures context-aware, high-quality outputs suitable for various professional and social communication needs. By leveraging fine-tuned models and manually curated datasets, ToneCraft delivers contextually adaptive tone transformations, making it an essential tool for business communication, customer interactions, and professional writing.

KEYWORDS : *Tone conversion, Text style transfer, NLP, Professional and friendly tone, Adaptive communication, AI-driven writing.*

INTRODUCTION

Background

Effective communication is not just about content but also tone, which significantly impacts clarity, professionalism, and engagement. In business, academia, and customer interactions, the ability to adjust tone appropriately is crucial. However, manual tone modification is time-consuming and often inconsistent, leading to misunderstandings or ineffective messaging.

Existing solutions for tone adjustment include manual rewriting, predefined templates, and basic AI-powered text generators. While these methods offer some level of customization, they often fail to capture context, leading to rigid or unnatural transformations. Many AI-based tools lack adaptability, producing repetitive outputs that do not align with the user's intent.

To address these challenges, ToneCraft introduces an AI-driven tone conversion framework that ensures seamless transformations between professional and friendly tones while preserving meaning. Leveraging BERT for classification and T5 for text generation, ToneCraft

enables more context-aware, diverse, and natural tone adjustments. This makes it a valuable tool for businesses, educators, and professionals seeking efficient and high-quality tone refinement.

Problem Statement

Effective communication relies not only on content but also on tone, which influences clarity, engagement, and professionalism. Miscommunication due to inappropriate tone can lead to misunderstandings and reduced effectiveness in professional and personal interactions. Existing tools often fail to provide context-aware tone adjustments, resulting in rigid or inaccurate modifications. There is a need for an intelligent solution that seamlessly transforms text between professional and friendly tones while preserving meaning and context. ToneCraft addresses this challenge by leveraging advanced language models to deliver adaptive and natural tone conversions, enhancing communication efficiency across various domains.

Objectives

Enhance Communication by developing an AI-powered platform that provides seamless tone conversion between

professional and friendly styles. By leveraging advanced language models, users receive accurate and context-aware transformations to improve clarity and engagement. The system ensures efficiency and maintains the intended meaning while adapting to different communication needs.

Ensure Context Awareness by utilizing deep learning models such as BERT for classification and T5 for text transformation. This approach allows for precise modifications while preserving context, tone, and intent in various professional and social interactions.

Improve Efficiency by reducing the time and effort required for manual tone adjustments. Automating the process enables users to quickly refine their messages while maintaining natural linguistic flow, making communication more effective and streamlined.

Enhance Text Diversity by generating multiple variations of transformed text, ensuring natural and adaptive outputs. This feature prevents repetitive phrasing and provides users with a range of options tailored to their specific needs.

Provide a User-Friendly Solution by designing an intuitive and accessible interface that caters to professionals, businesses, and customer service interactions. The goal is to offer a practical tool that enhances communication across various domains without requiring extensive technical knowledge.

LITERATURE REVIEW

Paper Title: “BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding”

BERT (Bidirectional Encoder Representations from Transformers) is a groundbreaking NLP model that leverages deep bidirectional context learning to improve language understanding. Unlike traditional unidirectional models, BERT’s masked language modeling (MLM) and next sentence prediction (NSP) techniques allow it to pre-train on vast corpora and then fine-tune on specific downstream tasks. The model achieves state-of-the-art results in text classification, sentiment analysis, and natural language inference.

Key Findings

- **Context-Aware Language Understanding:** BERT’s bidirectional nature enables more accurate text representation by considering both left and right contexts.
- **Superior Performance in NLP Tasks:** Outperforms

previous models in question answering, text classification, and paraphrase detection.

- **Fine-Tuning Flexibility:** Can be adapted for various tasks with minimal architecture modifications.
- **Impact on Tone Classification:** Forms the basis of ToneCraft’s classification module, ensuring precise tone identification before text transformation.

Limitations

- **Computationally Expensive:** Requires high processing power and large datasets for pre-training and fine-tuning.

Paper Title: “Controlled Text Generation using T5-Based Encoder-Decoder Soft Prompt Tuning”

This study explores controlled text generation using T5 with soft prompt tuning at both the encoder and decoder levels. The approach enhances model adaptability and enables fine-tuned text transformations based on desired attributes such as sentiment, tone, or style. The paper evaluates different tuning strategies and demonstrates that decoder-level soft prompting improves control over text generation.

Key Findings

- **Dual Soft Prompting:** Improves generation quality and attribute-specific text control.
- **Fine-Tuning Efficiency:** Reduces the need for full model fine-tuning, making the process computationally efficient.
- **Enhanced Text Customization:** Enables precise control over generated text, making it ideal for tone conversion applications like ToneCraft.
- **T5 Model Adaptability:** Demonstrates T5’s capability in structured text transformation tasks.

Limitations

- **Dependency on High-Quality Prompts:** The effectiveness of soft prompting relies on well-crafted input conditions.

Paper Title: “Exploring the Limits of Transfer Learning with a Unified Text-to-Text Transformer (T5)”

This paper, published by Google Research, introduces T5 (Text-to-Text Transfer Transformer) as a unified framework for handling diverse natural language processing (NLP) tasks. Unlike traditional models that require task-specific

architectures, T5 converts all NLP problems into a text-to-text format, making it adaptable for tasks such as translation, summarization, question answering, and text generation. By pre-training on a massive dataset (C4: Colossal Clean Crawled Corpus), T5 achieves state-of-the-art results across multiple NLP benchmarks.

Key Findings:

- **Text-to-Text Framework:** Treats all NLP tasks as sequence generation problems, allowing for a single model architecture across multiple tasks.
- **Pre-Training with C4 Dataset:** Utilizes a large-scale corpus of web-scraped text, improving model robustness and generalization.
- **Scalability & Performance:** Larger versions of T5 outperform previous models in summarization, translation, and classification tasks.
- **Fine-Tuning Efficiency:** Demonstrates high adaptability to domain-specific tasks with minimal architecture modifications, making it ideal for tone transformation applications like ToneCraft.

Limitations

- **Computational Cost:** Larger T5 models require significant processing power and memory, making them resource-intensive for fine-tuning.

METHODOLOGY

System Architecture

ToneCraft is a context-aware tone conversion system that processes text inputs, classifies their tone, and transforms them into the desired tone (professional or friendly) while maintaining meaning and coherence. The architecture consists of four key modules: Input Processing, Tone Conversion, Output Refinement, and User Interface & API Integration.

Input Processing Module

BERT-Based Tone Classification

- The system first determines the existing tone of the input text using a fine-tuned BERT model.
- The BERT classifier is trained on a labeled dataset containing examples of professional, friendly, and neutral tones.
- When a user provides input, the text is tokenized and passed through the BERT model, which outputs a

probability score for each tone category.

- Based on the classification, the system decides whether fine-tuning adjustments are needed before conversion.

Example

Input: "Hey, can you send me the report?"

BERT Classifier Output: Friendly Tone (85%), Neutral (10%), Professional (5%)

Tone Conversion Module

T5-Based Fine-Tuning for Tone Transformation

- Once the tone is classified, the T5 model is used for tone transformation.
- T5 is fine-tuned using a dataset where each example has parallel sentences written in professional and friendly tones.
- Training is done using the text-to-text format, where:
 - Input: "Convert to professional: Hey, can you send me the report?"
 - Target Output: "Please provide the report at your earliest convenience."
- The model learns the patterns in sentence structure, vocabulary, and politeness while ensuring the meaning remains intact.
- Soft prompt tuning is used to allow controlled transformations without modifying the entire model, making it more efficient for real-time applications.

Output Refinement Module

Post-Processing for Fluency & Contextual Consistency

- The generated text is evaluated for fluency, grammar, and coherence using automated post-processing techniques.
- The system ensures that the transformed text:
 - Retains urgency when needed (e.g., in workplace communications).
 - Maintains sentence structure and readability without excessive formality.
 - Avoids repetitive or unnatural phrasing, a common issue in text generation models.
- A secondary rule-based filter checks for unwanted artifacts, such as redundant phrases or overly softened

language.

Example Output Refinement:

- Before Refinement: “Would it be possible for you to kindly provide the report at your earliest convenience, please?”
- After Refinement: “Please provide the report at your earliest convenience.”

User Interface & API Integration

User Interface (UI) Design

- ToneCraft features a simple and intuitive UI where users can:
 - o Enter text for tone conversion.
 - o Choose between professional or friendly tone transformations.

Final Flow of the System

1. User Inputs Text → BERT classifies the tone.
2. T5 Generates the Transformed Output → Soft prompt tuning ensures controlled adjustments.
3. Output Refinement Ensures Clarity & Coherence → Grammar, fluency, and structure are optimized.
4. User Receives Final Text → Available via UI or API.

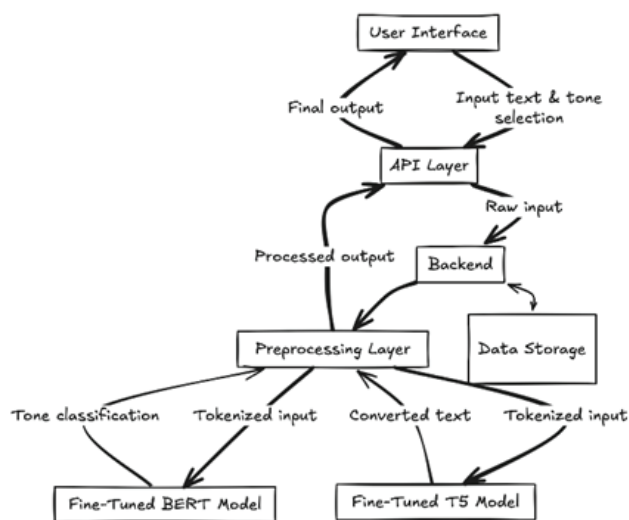


Fig. 1: ToneCraft System Architecture.

Model Training and Data Preparation

ToneCraft’s model planning involves a two-stage approach, where a fine-tuned BERT model classifies the input text’s

tone, and a T5-based model transforms it into the desired style. The BERT classifier is trained on a labeled dataset of professional, friendly, and neutral sentences, while T5 is fine-tuned using a parallel corpus of text rewritten in different tones. Data preparation includes text cleaning, tokenization, and balancing to ensure high-quality training. Soft prompt tuning is applied to T5 for efficient adaptation without full retraining, enabling accurate and context-aware tone conversion for professional and friendly communication.

Evaluation and Performance Metrics

ToneCraft’s evaluation involves both automated metrics and human assessment to ensure accurate tone conversion. BERT’s classification performance is measured using accuracy, F1-score, precision, and recall, ensuring reliable tone detection. T5’s tone transformation is evaluated using BLEU, ROUGE, and BERTScore, assessing fluency, content preservation, and semantic similarity. Additionally, human evaluators review outputs for clarity, coherence, and tone accuracy, ensuring that the transformed text aligns naturally with professional or friendly communication standards.

User Experience (UX) Design

ToneCraft is designed with a simple and intuitive user interface (UI) to ensure a seamless experience for users. The platform features a clean layout where users can input text, select the desired tone (professional or friendly), and receive an instant transformation. The interface prioritizes ease of use, readability, and minimal distractions, making it accessible for professionals, businesses, and casual users alike. Real-time previews, interactive feedback options, and API integration enhance usability, allowing ToneCraft to be deployed across various applications, such as email editors, chat platforms, and content creation tools.

DISCUSSION

ToneCraft bridges automated text generation and tone adaptation, ensuring professional and friendly tones while maintaining context. Using BERT for tone classification, it accurately identifies input tone, while T5 with soft prompt tuning enables precise transformations without extensive retraining, reducing computational costs. Evaluation metrics such as BLEU, ROUGE, and BERTScore confirm fluency and coherence, with human assessments validating clarity and tone accuracy. However, challenges arise in handling mixed tones and cultural nuances. Improving dataset diversity, refining prompt engineering,

and incorporating real-time feedback could enhance adaptability. Future developments may focus on industry-specific applications like customer service, email drafting, and content marketing, positioning ToneCraft as a valuable tool for professionals and businesses.

CONCLUSION

ToneCraft is an AI-driven solution for context-aware tone conversion, transforming text between professional and friendly styles while preserving meaning. Leveraging BERT for classification and T5 with soft prompt tuning, it ensures accurate, fluent, and natural tone adaptation. Evaluation results confirm strong performance across automated metrics and human assessments, making it a reliable tool for diverse communication needs. Challenges include handling ambiguous tone inputs and ensuring broader contextual adaptability. Future improvements will focus on expanding dataset diversity, refining prompt tuning, and integrating real-time user feedback, enhancing its value for professionals, businesses, and AI-powered communication platforms.

FUTURE WORK

Future improvements to ToneCraft will expand tone conversion beyond professional and friendly styles, incorporating casual, authoritative, empathetic, and persuasive tones for greater versatility across social, business, academic, and customer communication. Enhancing real-time adaptability with user feedback and exploring multilingual tone conversion will further refine accuracy and cultural relevance. Optimizations in soft prompt tuning and reinforcement learning will improve context awareness and fluency, while integration with

speech-to-text systems could extend its applications to voice-based interactions. These advancements will position ToneCraft as a comprehensive AI tool for diverse communication needs across personal, professional, and creative domains.

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Deepfake Technology: Generation, Detection, and Ethical Implications

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ABSTRACT

This paper provides a comprehensive overview of the current landscape in deepfake video technology, focusing on the deep learning approaches used for generation and detection. It examines the recent techniques, datasets, and the challenges in the domain of deep fake videos and the ethical implications and future research directions in the domain. The paper also describes how GAN has been used to create realistic fake video in addition to then discusses different deployed deep learning models for fake content detection. The paper also addresses available datasets, benchmarks as well as the possible societal impacts of deep fakes with respect to misinformation, privacy, and security. This survey aims to review the cutting-edge techniques and tools that could help develop more advanced and effective detectors for deepfake.

KEYWORDS : *Generative adversarial networks (GANs), Deep learning, Deep fake detection.*

INTRODUCTION

Deepfake videos are realistic, synthetic, fake videos generated using deep learning techniques. This technology is potentially disruptive and has grave social implications in terms of trust, privacy, security, safety, and democratic stability. It is increasingly important to survey recent deepfake techniques, especially those based on deep learning, which are the most successful and widely applied[1].

Therefore, the core aspects and the most useful studies of deepfake video technologies, especially those based on deep learning, will be systematically surveyed. Types of deepfake methods will be described, dealing separately with deep learning methods used for generation and those for detection. The principal notions used by deepfake methods will be analyzed, as well as growing trends. Furthermore, the kinds of databases published for the growth of deepfake technologies will be summarized. Algorithms and methods for evaluating the credibility

or trustworthiness of videos will be reviewed, which is related to deepfake detection methods. There are many sophisticated ways to create deepfake videos beyond the GAN-based methods. Handcrafted features and temporal cues specific to deepfakes can be used to detect deepfakes more effectively. From the applications perspective, remote, low-resource, and real-time deepfake detection techniques will be discussed. A few assessments and core technical issues will be made available to inform future research and to encourage the creation of more professional and versatile deepfake techniques[2].

Objectives: This paper will give an overview of the current state of deepfake creation and detection technologies, and will also discuss the ethical issues surrounding these developments.

LITERATURE REVIEW

Deepfake technology, propelled by breakthroughs in models such as Generative Adversarial Networks (GANs), has emerged as an important field of study within computer

science. This section synthesizes existing research on deepfake generation, detection methodologies, and their broader implications, highlighting main themes then identifying gaps in the current body of knowledge.

Deepfake Generation Technologies

Deepfake generation mainly relies on Generative Adversarial Networks (GANs), which are a type of deep learning model designed to create and sustain deep learning systems. In this process, the generator produces fake data, while the discriminator checks how realistic that data is compared to actual data. The pioneering work by Goodfellow et al. (2014) laid the groundwork for GANs, which have since evolved into more sophisticated architectures[3]. Notably, Variants such as Progressive Growing GANs and StyleGAN have significantly improved the realism of generated images and videos[4].

Recent studies have explored the application of GANs in video generation, highlighting techniques such as temporal coherence and facial reenactment [5]. These approaches allow for the creation of highly convincing deepfake videos that can manipulate facial expressions and movements, raising ethical concerns regarding misinformation and privacy[6].

Autoencoders: Autoencoders play a crucial role in face-swapping by extracting and learning features from one person's face and then mapping those features onto another face. Tools like DeepFaceLab and Face Swap leverage this technique to create realistic face swaps[7]

Neural Rendering: Combines computer graphics and neural networks for realistic image synthesis, allowing enhanced facial expression and movement replication. These models are emerging as a competitive alternative, enhancing the quality and realism of generated content. Researchers like Li (2024) are exploring their potential[8].

The high realism of deepfake videos raises significant ethical concerns. Misinformation, privacy violations, and potential misuse in contexts like political propaganda and social media are pressing issues. Deepfake technologies find applications in entertainment, political propaganda, and social media. As highlighted by Hao (2024) and Khimi et al. (2024), these uses necessitate a careful balance between innovation and ethical considerations[9]

Addressing these concerns requires ongoing advancements in detection methods, cross-modal techniques, explainable AI, and robust datasets to safeguard privacy and ensure the responsible use of deepfakes.

Deepfake Detection Techniques

Early detection methods mostly depended on traditional machine learning techniques, which often had a tough time keeping up with the fast-paced developments in deepfake technology[10]. However, recent research has shifted towards deep learning-based detection methods, leveraging convolutional neural networks (CNNs) and recurrent neural networks (RNNs) to examine both temporal and spatial elements in videos.

A light-weight CNN aimed specifically at manipulations in face areas. XceptionNet: A more aggressive architecture for the detection of deepfake videos from artifacts on Face Forensics++ outperforms any of the presented techniques[11]The proposal for combining CNNs with RNNs that allow the latter to capture video frame temporal inconsistencies would improve detection[12].

Combined audio and video streams to detect the inconsistency between what is spoken versus facial movements[13]. Zhou et al., 2021 proposed cross-modal analysis techniques that relied on both visual and linguistic cues[8]. One prominent theme in the detection literature is the creation of ensemble methods that bring together various models to enhance accuracy. Additionally, the integration of explainable AI techniques has become a critical area of research, aiming to provide transparency in detection outcomes and improve trust in automated systems[2]. Additionally, the integration of explainable AI techniques has become a critical area of research, aiming to provide transparency in detection outcomes and improve trust in automated systems.

Even with these advancements, the persistent arms race between creating deepfakes and detecting them remains a challenge. Numerous detection models find it difficult to generalize across various datasets, highlighting the necessity for more effective training methods. Many detection models struggle with generalizability across diverse datasets, indicating a need for more robust training methodologies. Furthermore, the effectiveness of detection systems often diminishes with the increasing sophistication of generative techniques, underscoring the necessity for continual innovation in detection strategies, techniques based on spatial and frequency domain analysis, using intra-frame and inter-frame features, are crucial for distinguishing anomalies in videos[14]. Other deep learning algorithms are being developed to enhance detection accuracy, addressing the drawbacks of existing techniques. The fast-paced evolution of generation

techniques necessitates continuous advancements in detection methodologies. Researchers must stay vigilant and innovative to address these challenges, Deepfake technologies indeed pose severe threats to personal privacy and social stability. Developing robust detection methods is crucial for reducing these threats and ensuring the responsible use of deepfake technology.

Ethical Implications and Societal Impact

The implications of deepfake technologies extend beyond technical considerations, encompassing ethical, legal, and societal dimensions. Individuals can become victims of deepfake pornography or other forms of non-consensual deepfake content, leading to severe emotional and psychological distress. The potential for deepfakes to propagate misinformation and manipulate public opinion has garnered significant attention from scholars and policymakers alike (Chesney & Citron, 2019). The intersection of deepfake technology with issues of consent, privacy, and authenticity raises critical ethical questions that demand thorough exploration[15]. Research has emphasized the significant psychological effects of deepfakes on individuals and society. Studies indicate that encountering deepfake material might undermine trust in media and institutions (Hwang et al., 2020)[16].

Furthermore, the risk of deepfakes being used as a tool in political contexts poses significant risks, necessitating the development of regulatory frameworks to mitigate harm (West, 2019)[17].

Modern Advancements and Regulation

Improved Generative Models: Models like StyleGAN2, StyleGAN3 and diffusion models further enhanced the quality and practicality of synthetic media.

Applications expanded into virtual reality, video games, and film production, demonstrating legitimate uses for deepfake technology. **Growth of Deepfake Detection Tools:** Governments and tech companies invested heavily in creating detection algorithms. AI-based tools like XceptionNet and multimodal systems became the standard for identifying manipulated media[18].

Ethical and Legal Developments: Laws against non-consensual deepfakes were introduced in several countries. Deepfake technology has become quite the double-edged sword. On one hand, it opens the door to innovative uses in fields such as entertainment and education. It also poses significant challenges in cybersecurity, misinformation, and privacy. Ongoing research aims to mitigate these risks through advanced detection systems, public awareness campaigns, and regulatory frameworks[19].

Table 1: Summary of related work

Paper	Gap	Advantages	Algorithm Used
Emerged in 2017 with face swapping videos[20].	Difficulty in distinguishing between real and fake media	Enhances creative arts, advertising, and film production.	Generative Adversarial Networks (GANs)
Early attempts traced back to 1865 with Abraham Lincoln photo manipulation[21].	Need for robust detection methods to prevent misuse	Potential for advanced applications in various fields	Machine Learning (ML) and Artificial Neural Networks (ANN)
Rapid advancements in machine learning have made deepfakes more realistic[22].	Legal and ethical concerns over privacy and misinformation	Streamlines mission planning and decision-making in space exploration	StyleGAN and BigGAN
Systematic review of deepfake detection techniques published in 2024[22].	Need for instant identification and assessment of digital media authenticity	Provides valuable insights for researchers and practitioners	Machine Learning (ML), Deep Learning (DL)
Comprehensive survey on deepfake generation and detection published in 2024[23].	Challenges in detecting high-quality deepfakes	Advances research in deepfake detection and generation.	Variational Autoencoders (VA), Generative Adversarial Networks (GANs), Diffusion Models (DM)

Challenges in Detecting Deepfakes

Deepfake detection becomes more challenging because of the better realism of synthetic media. Most of the detection methods excel on a given dataset but tend

to fail on real-world tests termed as Generalizability. Methods to circumvent the detection model can easily surpass traditional detection pipelines. In lack of large-scale datasets, the availability of high-quality, annotated

datasets is scarce, preventing the development of strong detection algorithms[24].

Advanced techniques produce highly realistic videos, making it harder for humans and even algorithms to detect them. Subtle anomalies (e.g., inconsistencies in lighting, blinking, or lip-syncing) may not be noticeable. Misuse in creating deceptive political or personal content can harm reputations and trust. Difficulty in distinguishing genuine content from manipulated media[25].

STANDARD DATASETS FOR DEEPPFAKE GENERATION

Several datasets were curated to train and evaluate algorithms for deepfake detection like Face Forensics is offering manipulated videos created with various processes.

Deep-Fake Detection Challenge, Facebook, released good quality videos that can be used to test deepfakes for detection purposes. Celeb-DF provides challenging deepfake samples containing less noticeable artifacts[26]. These datasets are used to train generative models like GANs and autoencoders for creating realistic synthetic media.

CelebA: is a vast dataset featuring the face of numerous celebrities, complete with detailed annotation about different facial attributes. It is commonly utilized for tasks such as face swapping and editing specific attributes.

FFHQ (Flickr-Faces-HQ): Contains high-quality facial images with diverse age, ethnicity, and image background attributes. Used in training models like StyleGAN[27].

VoxCeleb: Features audiovisual data of public figures. Supports video-based deepfake creation, including lip-syncing and voice synthesis.

FUTURE DIRECTIONS AND IMPLICATIONS OF DEEPPFAKE TECHNOLOGY

Recent advancements in generative models, such as StyleGAN3 and diffusion models, have made synthetic media increasingly realistic[27]. Future developments are expected to focus on enhancing the quality and detail of deepfake content, making the task of distinguishing real from fake increasingly challenging. Deepfakes offer opportunities for creating realistic visual effects and virtual characters in films and video games. Also,

Marketers can leverage deepfake technology for interactive and personalized campaigns, tailoring content for diverse audiences. In Education and Training the realistic simulations and avatars can transform e-learning environments, making training scenarios more immersive and effective.

The growing prevalence of deepfake technology necessitates robust ethical guidelines and legal regulations to prevent misuse. Ensuring individuals' images or likenesses are not manipulated without permission. Protecting sensitive information from exploitation and combating the spread of false narratives and digital manipulation.

Cutting-edge approaches include Cross-modal analysis i.e. Leveraging multiple data modalities (e.g., audio and visual) to detect inconsistencies. Explainable AI which is increasing transparency in detection methods to build trust and understanding in their outcomes. Blockchain and Distributed Ledgers, these technologies can enhance the traceability and authenticity of media content, providing secure methods for verifying digital assets. Watermarking and Metadata Standards are embedding digital signatures or timestamps to verify media authenticity[28]. Deepfakes have profound social implications, including their potential use in influencing public opinion i.e. Manipulated videos could sway political outcomes or spread propaganda and disrupting social media dynamics i.e. Fake content could erode trust in platforms and exacerbate misinformation. To mitigate these risks, fostering digital literacy and trust in media verification tools is critical[29].

CONCLUSION

The rapid evolution of deepfake technology and its reliance on advanced deep learning algorithms present significant security and privacy challenges. While detection methods focusing on facial landmarks, mesoscopic features, and audio-visual synchronization have made substantial progress, challenges such as adversarial robustness, dataset limitations, and generalization remain unresolved. Future research must prioritize the development of cross-modal techniques, explainable AI models, and robust benchmark datasets to enhance detection capabilities. As AI technologies continue to progress, it is vital to maintain vigilance and invest in cutting-edge detection strategies to safeguard personal privacy, address malicious misuse, and ensure social stability in an increasingly digital.

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Web Based Selector – Applicant Simulation Software

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ABSTRACT

This project develops a “Web Based Selector – Applicant Simulation Software” that helps users prepare for real-world job interviews through domain-specific mock sessions. Users can register, log in, and choose from technical domains like Machine Learning, Java, and Android. The system presents 10 domain-specific questions, and users respond via audio while machine learning algorithms analyze their facial expressions and voice tone. Facial analysis detects emotions such as confidence and nervousness by examining features like smiles and eye contact, while voice analysis evaluates speech rate, pitch, and tone variations. After the interview, the system generates a detailed performance report with feedback on verbal responses, non-verbal cues, and confidence levels, along with suggestions for improvement to enhance interview skills.

KEYWORDS : *Smart interview system, Mock interviews, Domain-specific questions, Facial expression analysis, Voice tone analysis, Machine learning.*

INTRODUCTION

In today's highly competitive job market, succeeding in interviews is a critical step toward securing employment. An interview is not only a test of technical knowledge but also a reflection of a candidate's communication skills, confidence, and emotional intelligence. However, traditional approaches to interview preparation often emphasize technical proficiency while neglecting the critical non-verbal aspects of communication. These overlooked areas—such as body language, facial expressions, and voice modulation—can significantly influence an interviewer's perception and ultimately determine a candidate's success.

Recognizing these challenges, we propose a Web-Based Selector–Applicant Simulation Software, designed to bridge the gap in interview preparation. The system integrates advanced machine learning techniques to create a platform where candidates can practice domain-specific mock interviews while receiving detailed, real-time feedback on their performance. This innovative

solution caters to both technical and behavioral aspects of interview readiness, ensuring holistic preparation for real-world scenarios.

The proposed system provides a user-friendly interface for candidates to register, log in, and participate in mock interviews tailored to specific domains such as Machine Learning, Java, and Android. Users answer a set of domain-specific questions via audio responses. During these sessions, the system captures and analyzes the candidates' verbal and non-verbal cues. Advanced machine learning algorithms assess speech content for accuracy and coherence while evaluating facial expressions and vocal tone for indicators of confidence, attentiveness, and emotional state.

The facial expression analysis module detects subtle emotional cues such as smiles, frowns, and eye movements, which are critical indicators of confidence and engagement. Similarly, the voice tone analysis component evaluates speech rate, pitch, and tonal variation to assess stress levels, confidence, and overall emotional stability. By

leveraging these insights, the system provides candidates with actionable feedback and personalized suggestions for improvement, thereby addressing the nuanced aspects of interview preparation.

This comprehensive approach to mock interviews not only enhances technical proficiency but also builds the soft skills that are indispensable in professional settings. The system aims to empower candidates by fostering self-awareness and equipping them with the tools to excel in high-pressure interview environments.

PROBLEM STATEMENT

The primary problem faced by candidates during interview preparation is the lack of a comprehensive system that evaluates both technical knowledge and non-verbal communication skills. While most candidates focus heavily on answering technical questions, they often neglect important soft skills such as facial expressions, voice tone, and confidence. This results in poor performance during real interviews, even when they have the right answers. Current interview preparation methods and platforms mainly assess technical abilities, without providing any feedback on the non-verbal cues that influence interview outcomes. Consequently, candidates are not fully prepared for real interviews, where both technical expertise and communication skills are crucial for success. There is a clear need for an integrated system that can test and provide feedback on both technical and behavioral aspects of an interview, helping candidates improve holistically.

OBJECTIVE

1. Provide Domain-Specific Mock Interviews Allow users to practice mock interviews in various domains such as Machine Learning, Java, Android, etc.
2. Analyze Verbal Responses Evaluate users answers to interview questions based on their content, accuracy, and communication skills.
3. Assess Non-Verbal Cues Use facial expression analysis and voice tone assessment to measure users' confidence and emotional state during the interview.
4. Generate Detailed Performance Reports provide a comprehensive report that includes feedback on both verbal and non-verbal communication, confidence levels, and emotional cues.
5. Offer Suggestions for Improvement Provide actionable insights and suggestions to help users

improve their interview performance, focusing on areas of weakness.

LITERATURE SURVEY

It is a system for public speaking practice that analyzes speech, facial expressions, and gestures. The system provides valuable feedback to improve confidence and overall performance during public speaking sessions. It helps individuals refine communication skills by evaluating their presentation in real-time using multimodal inputs.[1]

The System that assesses interview performance through machine learning techniques. It evaluates emotions, engagement, and confidence by analyzing audio and visual data during an interview. By offering detailed feedback, it helps candidates develop deeper self-awareness and identify areas for improvement.[2]

An emotion detection system designed to assist candidates in preparing for virtual interviews. By analyzing facial expressions and vocal cues, the system detects the emotional state of the candidate, offering real-time feedback to reduce interview anxiety and improve response quality, thus enhancing interview readiness. [3]

The combination of voice tone and facial expression analysis for candidate evaluation in virtual interviews. The study highlights how both vocal and facial cues assess a candidate's confidence and communication skills. The feedback provided guides individuals toward better interview performance by pinpointing strengths and areas needing attention. [4]

A Virtual Interview Assistant that uses facial and vocal emotion recognition to assess candidate emotions during interviews. The system provides valuable insights into emotional state, confidence, and interview readiness, thus offering a personalized approach to improving interview performance.[5]

SYSTEM ARCHITECTURE

The Web Based Selector – Applicant Simulation Software uses artificial intelligence (AI) and machine learning to analyze how users respond during a practice interview and provide useful feedback. For facial expression analysis, the system records video using a webcam and uses deep learning models to recognize emotions like confidence, nervousness, and engagement by analyzing facial features such as eye contact, smiles, and eyebrow movements. In voice analysis, the system listens to the user's speech, studying tone, pitch, and speaking speed to understand confidence levels.

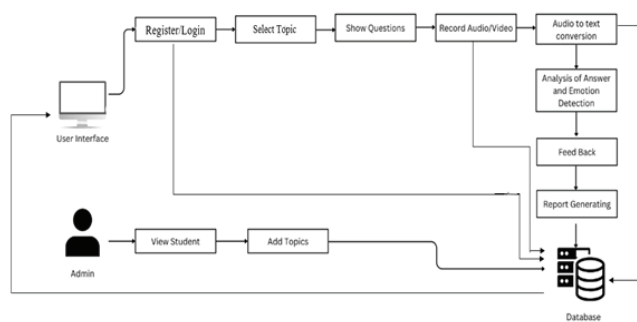


Fig. 1: Web Based Selector – Applicant Simulation Software

For answer evaluation, the system converts spoken answers into text using speech recognition software like Google Speech-to-Text. It then analyzes the response using language processing models to check if the answer is relevant, well-structured, and technically correct. Finally, the system creates a detailed performance report, rating the user's verbal responses, facial expressions, and confidence levels. It also provides personalized feedback and suggestions for improvement. By combining AI-powered speech, facial analysis, and smart feedback, the system helps users get better at interviews by improving both their technical answers and body language.

The system architecture consists of several interconnected components:

User Interface (UI): The user selects a topic, gives permission, and records audio/video responses. The UI is connected to the database for storing user data and session details.

Recording and Analysis: Audio and video responses are analyzed for emotional tone, content, and facial expressions using AI models.

Feedback and Report Generation: Based on the analysis, personalized feedback is generated and a report is created, which is accessible to the user.

Database (DB): Stores user profiles, media files, analysis results, and feedback.

Admin View: Administrators can add topics, manage users, and monitor progress through a separate interface connected to the database.

METHODOLOGY

Convolutional Neural Networks (CNNs) are employed to process video frames captured during mock interviews.

The system detects emotions such as confidence and nervousness by analysing visual features like eye movements, smiles, and facial expressions. The CNN model extracts and classifies these features in real-time, enabling the system to evaluate the user's non-verbal communication and engagement level.

Recurrent Neural Networks (RNNs) are utilized to analyze sequential audio data, assessing voice tone, pitch, and speech patterns. The system leverages RNNs, often combined with Long Short-Term Memory (LSTM) units, to capture temporal dependencies in the user's speech. This analysis helps identify stress, confidence, and emotional consistency throughout the interview, providing valuable insights into vocal delivery.

Gemini API models are integrated for generating domain-specific interview questions dynamically, ensuring relevance and variety. The system uses Cosine similarity algorithm to analyze user responses for technical accuracy, coherence, and content quality. Furthermore, it generates detailed, personalized feedback and actionable suggestions, helping users improve their technical knowledge and communication skills.

ALGORITHM

Speech Recognition

In a web-based applicant simulation software, speech recognition serves as a core technology to enable seamless interaction and real-time response evaluation during mock interviews. Speech Recognition library supports several speech-to-text engines, including Google's Web Speech API, the software transcribes the applicant's spoken responses into text, allowing the system to process and analyze them. This process is facilitated by machine learning models that ensure high accuracy in transcription, even in the presence of various accents, pronunciations, or background noise.

Natural Language Processing

The web-based applicant simulation software leverages advanced Natural Language Processing (NLP) techniques to enhance the interview preparation experience. NLP plays a critical role in generating role-specific interview questions tailored to the user's profile, based on the job description and required skills. During the mock interview, the software uses Speech Recognition, a subfield of NLP, to convert the user's spoken responses into text. Once transcribed, NLP algorithms analyze the content

of the answers, checking for relevance, structure, and key points. The Gemini API generates domain-specific questions, while the cosine similarity algorithm evaluates user responses against model answers for relevance and accuracy, ensuring precise feedback.

$$\cos(\theta) = \frac{\mathbf{A} \cdot \mathbf{B}}{\|\mathbf{A}\| \|\mathbf{B}\|} = \frac{\sum_{i=1}^n A_i B_i}{\sqrt{\sum_{i=1}^n A_i^2} \sqrt{\sum_{i=1}^n B_i^2}}$$

$\cos(\theta)$: Similarity score between the candidate's input and the ideal response.

$\mathbf{A} \cdot \mathbf{B}$: Alignment between the candidate's performance and the expected behaviour.

$\|\mathbf{A}\|$ and $\|\mathbf{B}\|$: Strengths of the candidate's input and the ideal response.

$\sum A_i B_i$: Agreement between the candidate's input and the expected response.

$\sqrt{\sum A_i^2}$ and $\sqrt{\sum B_i^2}$: Normalized magnitudes of input and expected response for comparison.

Facial Expression Recognition

1. Input Image Frame Extraction: Video feed from the candidate's camera is divided into individual image frames.
2. Preprocessing: Frames are resized and normalized to ensure uniformity in the input dimensions.
3. Feature Extraction (Convolutional Layers): The CNN applies convolution operations to extract features like eye movements, lip curvature, and facial expressions.
4. Pooling (Down sampling): Reduces the size of feature maps while retaining important features to make processing faster and more efficient.
5. Flattening: Converts the pooled feature maps into a 1D vector to prepare for classification.
6. Classification (Fully Connected Layers): The extracted features are analysed to classify facial expressions (e.g., neutral, nervous, confident). Output is a probability distribution over predefined emotion categories.
7. Integration with Feedback: The classified expressions are used to provide feedback on non-verbal cues, such as confidence and emotional presence.

Emotion Recognition from Voice Tone:

1. Input Audio Sequence Extraction: The candidate's speech is converted into audio frames and broken into sequences of features (e.g., pitch and tone)
2. Preprocessing: The audio signals are normalized to remove noise and ensure clarity. Text responses (if any) are tokenized into word sequences for analysis.
3. Feature Representation: Audio features (e.g., pitch and tone) or word embeddings (e.g., using Word2Vec or GloVe) are used as input vectors to the RNN.
4. Sequence Learning (RNN Layers): The RNN processes input sequences step by step, capturing patterns in tone, sentiment, or relevance over time.
5. Memory Management (LSTM/GRU): Long Short-Term Memory (LSTM) or Gated Recurrent Unit (GRU) layers are used to handle long-term dependencies, ensuring earlier parts of the answer are considered when evaluating the overall response.
6. Output Analysis: The RNN outputs scores for sentiment (e.g., confident, hesitant).
7. Integration with Feedback: Combines tone and semantic analysis to provide detailed feedback on verbal communication, including confidence level and content quality.

TECHNICAL EXPLANATION

The Mock Interview System is an advanced platform that revolutionizes interview preparation by integrating Recurrent Neural Networks (RNN) and Convolutional Neural Networks (CNN) to evaluate both technical knowledge and non-verbal communication. Users can select domains such as Machine Learning, Deep Learning, and Data Mining, etc. after which the system displays domain-specific questions for the candidate to answer. During the response, the platform analyzes the user's voice tone and facial expressions, providing insights into emotional presence and non-verbal cues. This comprehensive approach helps users understand and improve their confidence, communication skills, and emotional stability. By offering detailed feedback on strengths and areas for improvement, the system enables candidates to enhance their technical expertise and overall performance, preparing them for success in competitive job markets and real-world interviews.

FUNCTIONAL REQUIREMENTS

1. The system should allow users to register using their email, social media, or custom credentials.
2. Users should be able to securely log in to access the mock interview platform.
3. Users must be able to choose from multiple domains such as Machine Learning, Java, Android, etc.
4. The system should provide a list of relevant technical questions for each selected domain.
5. The system should present a set of 10 questions.
6. Users should be able to answer these questions using audio responses.
7. The system should use facial recognition to analyze the user's facial expressions.
8. It should also use voice tone analysis to assess confidence, stress levels, and emotional state.

NON FUNCTIONAL REQUIREMENTS

1. Usability: The system should have an intuitive user interface that is easy to navigate for both technical and non-technical users.
2. Performance: The system should process and analyze facial expressions and voice tone in real time with minimal delay. The mock interview should run smoothly, even for large numbers of users.
3. Scalability: The system should be able to scale to accommodate a large number of users without compromising performance.

CONCLUSION

In conclusion, the AI-driven interview simulation system offers a comprehensive solution for candidates looking to enhance their interview skills. By integrating real-time analysis of speech, facial expressions, and answer content, it provides a realistic and holistic evaluation of a user's performance. The post-interview in-depth analysis and personalized feedback ensure that users receive actionable insights, helping them identify areas for improvement and boosting their confidence. This innovative approach prepares candidates not only for technical questions but also for handling non-verbal communication effectively, making them better equipped for real-world interviews.

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An Overview, Significance, and Uses of Blockchain Technology

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ABSTRACT

Blockchain operates without a central authority. Transactions are validated by a distributed network of participants nodes, ensuring trust and transparency. Because of this technology, the recorded data is transparent and unchangeable, making it difficult for illegal changes to take place. Through the use of cryptographic algorithms, blockchain improves security and builds user trust, enabling a range of applications beyond cryptocurrencies, such as voting systems, healthcare, and supply chain management.

This paper provides an in-depth review of blockchain technology, emphasizing its importance and exploring its diverse applications. The challenges and potential future directions are also discussed to provide a comprehensive understanding of this transformative technology.

KEYWORDS : *Blockchain, Security, Healthcare, Supply chain, Voting system.*

INTRODUCTION

A distributed ledger system called blockchain technology offers immutability, security, and transparency.

It was first presented by Satoshi Nakamoto in 2008 [1] through the Bitcoin white paper.

Blockchain removes the need for middlemen and increases stakeholder confidence by decentralizing data management.

This paper explores blockchain's fundamental principles, significance, and real-world applications, alongside the challenges that hinder its widespread adoption.

The potential of blockchain extends beyond the technical domain, influencing societal, economic, and governmental structures.

This intersection of technology and societal impact underscores the importance of understanding blockchain's broader implications.

The Foundations of Blockchain Technology

Core Principles Blockchain is a decentralized ledger comprising sequential blocks of data, each containing transaction information, timestamps, and cryptographic hashes that establish a connection to the prior block. The integrity and immutability of the data stored are guaranteed by this structure [2,3].

As we know that blockchain methodology is distinct, no single entity has influence over the network, distributing power and decision-making across participants. This feature enhances trust and reduces the risk of manipulation.

Consensus Mechanisms The techniques that guarantee that every member of a distributed network agrees on a particular data value or network state are known as consensus mechanisms [4].

Key mechanisms include:

- Proof of Work (PoW):

Blockchain and distributed systems employ Proof of Work (PoW), a consensus process, to guarantee security, stop spam, and validate transactions. Before adding a new block to the blockchain, participants (miners) must solve a mathematical challenge that demands a lot of processing.

- Proof of Stake (PoS): It seeks to offer a more secure, scalable, and energy efficient way to validate transactions and generate new blocks[5].
- Delegated Proof of Stake (DPoS): Stakeholders elect trusted nodes as validators.
- Practical Byzantine Fault Tolerance (PBFT): Ensures reliability in distributed systems, suitable for permissioned blockchains.

Smart Contracts Blockchain-stored self-executing codes are known as smart contracts, which automating agreements and reducing reliance on intermediaries. Their integration into decentralized applications (dApps) has paved the way for innovations across industries, from insurance to gaming.

Working of Blockchain Technology Blockchain technology operates through a series of well-defined steps that ensure data integrity, security, and transparency. Below is a detailed explanation of the process:

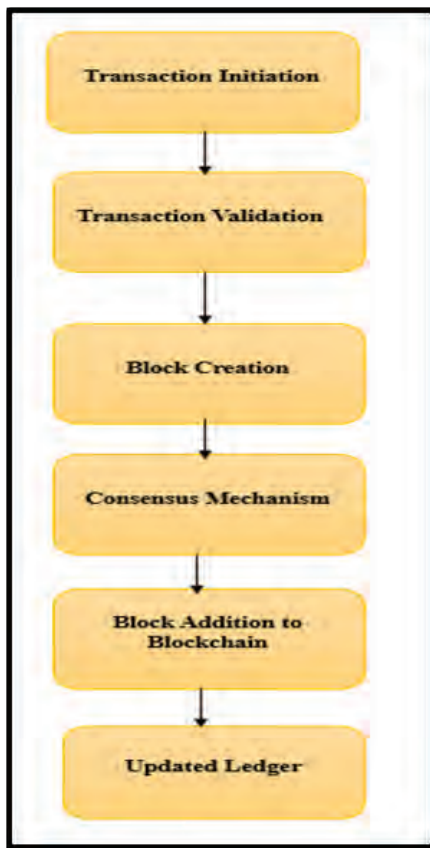


Fig. 1: Working of Blockchain Technology

Steps in the Blockchain Process:

1. **Transaction Initiation:** A transaction is started by a user and disseminated to the network. For instance, transferring cryptocurrency or recording supply chain data.
2. **Transaction Validation:** Consensus techniques are used by network nodes to verify the transaction. They ensure that the transaction adheres to predefined rules and that the user has sufficient resources.
3. **Block Creation:** A block is made up of all validated transactions. A reference to the hash of the previous block, transaction data, and a unique identifier (hash) are all included in each block.
4. **Consensus Mechanism:** Network participants (nodes) reach an agreement to approve the block. To guarantee that only legitimate transactions are appended to the blockchain, common methods include Proof of Work, Proof of Stake, and others.
5. **Block Addition to Blockchain:** The new block is appended to the current blockchain upon reaching consensus. This addition acts as a permanent record and cannot be changed.
6. **Updated Ledger:** All nodes update their copies of the blockchain, ensuring consistency across the network. This distributed nature enhances security and prevents tampering.

IMPORTANCE OF BLOCKCHAIN TECHNOLOGY

Enhanced Security Blockchain's cryptographic foundation which assures that data is secure from illegal modifications, enhancing trust and reducing fraud. It provides strong defence against cyberattacks because of its decentralized architecture, which makes it resistant to single points of failure.

Transparency Entire transactions on a blockchain are recorded and can be visible to authorized participants, fostering accountability and traceability. This transparency is specifically valuable in industries like finance and supply chain, where trust is paramount.

Decentralization The removal of centralized intermediaries reduces costs, improves efficiency, and mitigates single points of failure. Decentralization also empowers users by giving them greater control over their data and assets.

Immutability Blockchain's design prevents alteration of past transactions, ensuring data integrity. This immutability is critical for applications requiring historical accuracy, such as legal contracts and financial records.

Potential for Financial Inclusion By enabling decentralized financial systems, blockchain can provide unbanked populations access to essential financial services. Cryptocurrencies and decentralized finance platforms remove barriers associated with traditional banking [6,10].

APPLICATIONS OF BLOCKCHAIN TECHNOLOGY

Cryptocurrencies and Decentralized Finance (DeFi) Cryptocurrencies like Bitcoin and Ethereum exemplify blockchain's ability to enable secure, peer-to-peer financial transactions. DeFi extends this functionality, offering decentralized lending, borrowing, and trading platforms. Innovations like stablecoins and yield farming highlight the dynamic growth of DeFi.

Supply Chain Management

By allowing stakeholders to track products from point of origin to point of destination, blockchain improves supply chain transparency. It ensures real-time data sharing among parties and reduces inefficiencies, fraud, and counterfeit products [7]. The detailed structure of supply chain management using blockchain includes the following components:

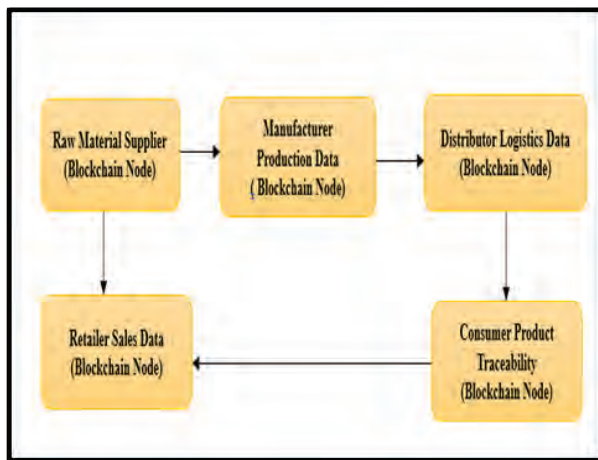


Fig. 2:Supply Chain Management Using Blockchain

Detailed Structure

1. Raw Material Supplier: Data such as material origin, quality, and compliance certifications are recorded on the blockchain.
2. Manufacturer: Information on production processes, batch numbers, and assembly details are stored. This ensures transparency in the manufacturing phase.
3. Distributor: Logistics and shipment details, including real-time tracking and handling conditions, are recorded on the blockchain.
4. Retailer: Retailers can access verified data regarding product origin, manufacturing, and logistics, ensuring authenticity.

5. Consumer: Consumers can trace the entire lifecycle of a product using blockchain-based apps, increasing trust and enabling informed decisions.

Applications of blockchain in supply chain management include:

- Food Safety: Tracking food items to ensure freshness and safety (e.g., Walmart's use of IBM Food Trust).
- Pharmaceuticals: Preventing counterfeit drugs by tracking distribution channels.
- Luxury Goods: Verifying the authenticity of high-value items like jewellery and watches.

Healthcare Blockchain protects patient information, makes it easier for healthcare providers to communicate with one another, and guarantees the accuracy of medical records. Solutions like MediLedger streamline drug traceability, preventing counterfeit medicines from entering the market [8,9].

Voting Systems Blockchain-based voting ensures transparency, prevents tampering, and promotes voter confidence. Systems like Voatz have been tested in pilot elections. Blockchain's ability to provide verifiable and tamper-proof records makes it an ideal solution for electoral processes.

Intellectual Property Rights Blockchain provides a verifiable record of ownership and licensing, protecting intellectual property and combating counterfeiting. Platforms like Ascribe and OpenSea leverage blockchain for digital rights management and art ownership.

Energy and Sustainability Decentralized energy grids and carbon credit tracking are emerging applications. Platforms like Power Ledger enable peer-to-peer energy trading, promoting renewable energy adoption and reducing carbon footprints.

Real Estate Blockchain simplifies property transactions by providing a transparent ledger for ownership records and contracts. This reduces fraud and increases efficiency in buying, selling, and leasing real estate.

CHALLENGES IN BLOCKCHAIN TECHNOLOGY

Scalability High transaction volumes are difficult for blockchains to manage, which leads to longer processing times and more expensive fees. The goal of scaling solutions like layer 2 protocols and sharding is to overcome these constraints [5].

Energy Consumption PoW-based systems consume significant energy, raising sustainability concerns. Transitioning to energy-efficient mechanisms, such as PoS, is vital for reducing environmental impact [4].

Regulatory Uncertainty The lack of standardized regulations globally hinders blockchain's growth and adoption. Regulatory clarity is essential for fostering trust and encouraging investment.

Interoperability Limited interaction between different blockchain networks creates silos, reducing the technology's overall effectiveness. Interoperability protocols like Polkadot and Cosmos are addressing this issue.

Security Risks While generally secure, vulnerabilities like smart contract bugs and 51% attacks pose significant threats. Enhanced security practices and regular audits are crucial for mitigating these risks.

FUTURE DIRECTIONS

Scalability Solutions Technological innovations like sharding, layer 2 solutions, and novel consensus mechanisms are addressing scalability issues. Continued advancements in these areas are critical for blockchain's mass adoption.

Sustainable Blockchain Efforts to adopt energy-efficient consensus mechanisms, such as PoS and green blockchain initiatives, aim to reduce environmental impact. Carbon-neutral blockchain networks are becoming a priority.

Interoperability Standards Developing universal standards and protocols will enable seamless communication and integration across blockchain platforms. Cross-chain solutions are essential for maximizing blockchain's potential.

AI and Blockchain Integration Combining blockchain with AI can enhance automation, data analysis, and decision-making in various sectors. This integration offers opportunities for predictive analytics and intelligent contract management.

Strengthening Security Advancements in cryptographic techniques and rigorous testing of smart contracts can mitigate security risks. Quantum-resistant algorithms may play a pivotal role in future blockchain security.

Policy Development Collaborative efforts among governments and organizations to establish clear, adaptive regulations will foster blockchain's global adoption. Public-private partnerships can accelerate policy alignment.

CONCLUSION

Blockchain technology represents a revolutionary step toward secure, decentralized systems that empower individuals and organizations alike. Its applications across diverse sectors demonstrate its transformative potential. However, addressing challenges like scalability, energy consumption, and regulatory hurdles is essential for sustained growth. Continued research and innovation will unlock new possibilities, cementing blockchain's role as a cornerstone of the digital era.

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A Compressive Review on- Privacy Preserving Technique in Private Blockchain for Healthcare

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ABSTRACT

The swift advancements in blockchain technology across multiple domains primarily pertain to decentralization, transparency, and security. By paying transaction fees to miners, the publishing and subscribing the network's nodes guarantee that transaction is entered into the ledger. The network uses various consensus techniques to provide security. Numerous industries, including healthcare, education, supply chains, auction systems, electronic voting, and more, heavily rely on blockchain approaches. As the healthcare sector increasingly depends on digital systems to manage sensitive patient data, concerns regarding privacy and security have become more pronounced. In response, Blockchain technology has become a viable way to improve data security. However, while Public blockchains provide immutability and transparency, these features can conflict with the need for confidentiality in healthcare. This paper investigates the use of private blockchains as a privacy-preserving framework for healthcare data management. Private blockchains, by design, allow for controlled access and permissioned participation, making them particularly suited for managing sensitive healthcare information. The paper reviews methods for improving privacy, including encryption, ZKPs, or zero-knowledge proofs, and SMPC, or secure multi-party computation, which can help safeguard patient data while allowing for secure data sharing among healthcare providers.

KEYWORDS : *Private blockchain, Electronic health record, Privacy, Security.*

INTRODUCTION

Healthcare departments, organizations, and hospitals using potentially various healthcare systems regularly develop and update important patient reports and information. Because of this, medical professionals find it difficult to obtain vital information when they need it to provide patients with high-quality data, such as diagnosis, treatment decisions, and suggestions for additional care. Besides, when clinical therapies are complicated and require assessment from medical services experts to get to the electronic clinical records (EMRs) of the patients going through therapy, there are deficiently proficient EMR sharing administrations and frameworks that give adaptability, control, and regulatory administration of ideal and secure admittance to appropriate EMR information. Internet of Things (IoT) technology is being incorporated into healthcare services by a large number of healthcare and medical facility providers. The need for quick, safe, and reliable EMR data-sharing infrastructure that can offer

transparent, economical, and easily navigable EMR data sharing whenever needed and in real time is demonstrated by scenarios for sharing medical information in real time. In order to provide better healthcare, a blockchain-based health system of information that handles private information of patient needs quick and secure access to medical records. With numerous benefits, the blockchain, a safe distributed ledger, offers a potential way to exchange medical data between platforms.[12]

1. Records of Chronological Patients
2. Verification of data without a central administrative body
3. Data verifiable assurance and secure storage with integrity
4. Secure data sharing

This review paper's scope will include a thorough investigation of privacy-preserving private blockchain

technology in the healthcare industry, with an emphasis on its uses, difficulties, advantages, and developments.

LITERATURE REVIEW

One author writes about privacy-preserving solutions for blockchain: review and difficulties using methods like Commitment Scheme, Homomorphic Hiding, zkSNARK, STARK, and Ring Signatures in article one. The current methods, including SMPC, ZKPs, ring signatures, homomorphic concealing, and mixings, are able to handle and successfully address most of the challenges that are faced, they conclude.

The two strategies outlined by the paper's author. Electronic health data, blockchain technology, and signatures based on identification [3]

Data integrity verification, smart contracts, attribute-based encryption, searchable symmetric encryption, blockchain, and fine-grained access control are all components of a new method for exchanging personal health information on the blockchain. [4].

The idea for a prototype that integrates Amazon Web Services' cloud computing with the Ethereum blockchain and a true information sharing situation on a portable application was put out in

A framework that uses ϵ -differential privacy for data from medical devices was designed by Alin Petru-Rosu, Tamara Tataru, Jegor Zelenjak, Roland Kromes, and Zekeriya Erkin in 2024. It provides better data security, greater privacy, and actionable insights for healthcare.

The study PAVA: Privacy-Preserving Attribute-Based Verifiable Authentication in Healthcare Using Smart Contracts was published by Mostafa Chegenizadeh and Claudio J. Tessone. It is an attribute-based approach that protects privacy and employs smart contracts for verifiable authentication. It maintains secrecy from unauthorized parties by implementing dual access procedures for data encryption (providers) and decryption (users)

OVERVIEW OF PRIVACY PRESERVING TECHNIQUES

Weaknesses in Cryptographic Algorithms: Complex cryptography methods like homomorphic encryption and zero-knowledge proofs (ZKPs), or ring signatures, are usually used in privacy preserving blockchain to obscure sensitive information. Vulnerabilities in such algorithms or their poor implementation can be exploited in attacks to break the privacy guarantees.

1. **Smart Contract Vulnerabilities** - Blockchains often integrate smart contracts to facilitate complex interactions. If these contracts have bugs or security flaws, they could inadvertently expose private data or create attack vectors for malicious actors.
2. **Cross-Chain Interactions**- As blockchains become more interconnected with other blockchain networks, cross-chain transactions could inadvertently reveal private data. Even if one chain ensures privacy, bridging or interacting with other
3. **Quantum Computing Threat**: With the development of quantum computing, some of the cryptographic techniques currently employed in privacy-preserving blockchains—like elliptic curve cryptography, or some constructions of zero-knowledge proofs—may become vulnerable to attacks.

Privacy-Preserving Techniques

Privacy-preserving strategies are very important in the healthcare industry to protect sensitive patient information while facilitating the required information sharing and analysis. These strategies cover a variety of tactics, such as blockchain technology, access control systems, privacy-preserving machine learning, data anonymization, and sophisticated cryptography techniques. Every one of these tactics is intended to tackle distinct privacy issues, guaranteeing the privacy, accuracy, and safe exchange of medical information among different parties.

Data Anonymization-

- **Anonymity**: This method ensures that no person in a data set can be distinguished from at least $k-1$ other persons based on their identifying attributes. This is achieved by generalizing or suppressing certain data fields (such as age or location), making the set of quasi-identifiers indistinguishable among k persons. For example, a data set may group ages into ranges (such as 30-40) rather than using exact ages.
- **Diversity**: This is one type of k -anonymity where it ensures that for any group of k individuals, for the sensitive attributes, such as medical conditions, at least l values will be unlike each other. So, even though the attacker knows quasi-identifiers about the person, he cannot determine sensitive information about him/her.
- **t-Closeness**: It improves upon the l -diversity approach. In this method, It guarantees that the

sensitive attribute distribution within a particular group closely resembles the dataset's overall distribution.. Preserving the statistical properties of the sensitive attributes leads to decrease the possibility of inferring sensitive information from the value distributions.

3.2 Cryptographic Approaches

Homomorphic Encryption

Another method for sharing and modifying data without revealing personal information or actual text is homomorphic encryption. The source of it is privacy homomorphism. The encryption function may process ciphertext and produce encrypted output identical to that which would have resulted from applying the function to plain text and then encrypting it, according to certain features of the function. The RSA encryption system is among the most obvious instances of homomorphic concealment. Given a private key (d) and a public key (e, n), that is, numbers that verify that $d \cdot e \equiv 1 \pmod{\phi(n)}$ and $n = p \cdot q$ with p and q prime.

Bitcoin ECDSA key pairs are another obvious use of homomorphic encryption in blockchain technology. These key pairs are renowned for having additive and multiplicative homomorphic features. Bob buys Alice his address (b, B) by making B, b , and $A + B$ public. Bob says that the coin can only be spent by people who know the secret key $a + b$, which Alice can only calculate with a . This creates a third valid Bitcoin address. A key pair (a, A) represents the private and public values, respectively, and another pair (b, B) can create a third valid Bitcoin address by adding the keys as ($a+b, A+B$). In this manner, Bob can sell Alice the address without needing to safeguard any private key delivery.

Secure Multiparty Computation (SMPC)-

In secure multi-party computation (SMPC), P parties share secrets in order to partition data or program states (like a blockchain's smart contract states). It takes P out of N nodes working together to do distributed computing on an input, which will provide an output that will expose data or program states.

Real SMPC methods are finally making it into production, joining the ranks of oblivious RAM structures, HE, GC, and LSS. According to a record intended to work with the exchange of computerized resources between a few blockchain networks, SMPC might be utilized to blockchain to decouple the execution of brilliant agreements from record and key administration, all without involving any

third parties. To prevent any one node from gaining access to the whole private key of an initial account, storeman nodes administer smart contracts that lock assets on the original chain while keeping part of the private keys. [12]

Differential Privacy-

Protecting individuals' privacy, differential privacy checks to see whether a data analysis technique reveals any personally identifiable information.

Although inference over any one individual is impossible, some random noise is included into data searches to make statistical analysis over the full collection substantially near to the actual results. By using differential privacy in blockchain, it is feasible to get to private data sets by utilizing questions that total the information, procure individual information with measurable deviations from the sources, and decrease the quantity of personally identifiable information (PII) collected from individuals. Private blockchains that permit third parties to use their anonymised data can be used in the first database scenario.

The second example pertains to blockchains that gather data from sensors or logs; in these situations, a single transaction may have statistically moved data, even though the entire chain may be statistically examined. When using differential privacy, there is a compromise between privacy and utility as it is difficult to completely anonymize information without undermining its scientific worth. Different differential protection methods achieve a specific degree of security, as shown by the definition's consistent and how much inquiries led after some time. [12]

Access Control Mechanisms

Role-Based Access Control (RBAC)-

Differential privacy examines whether or not a data analysis procedure reveals information about a person in order to protect private. It involves adding a random noise in data searches to a certain extent so that, while inference over any one individual is impossible, statistical analysis over the entire set is substantially near to the actual results. Differential privacy in blockchain can be used to access private databases by aggregating the data, retrieve individual data with statistical differences from the sources, and decrease the quantity of personally identifiable information (PII) collected from individuals.

The primary data set situation is pertinent to private blockchains that let outsiders admittance to their

anonymized information. The second scenario applies to blockchains that collect data from logs or sensors; in these cases, the entire chain may be statistically analyzed, but statistics have changed due to a single transaction. When using differential privacy, there is a compromise between privacy and utility as it is impossible to fully anonymize data without compromising its analytical value. Several differential privacy algorithms achieve a specified amount of privacy, as shown by the definition's consistent and the quantity of inquiries run over the long run. To protect user privacy in different situations, blockchain technology employs differential privacy.[2]

Attribute-Based Encryption (ABE)

Instead than relying just on user identities to encrypt data, Attribute-Based Encryption (ABE) takes into account certain user attributes. It provides fine-grained access control by encrypting data such that only users who possess a particular set of attributes may decode and access it. This technique is particularly useful when standard identity-based encryption, which uses user IDs like usernames or email addresses as keys, is unable to satisfy complex access control needs.

Blockchain for Privacy

Decentralization and Immutability

Based on their major goals in terms of privacy protection, the above mentioned strategies may be broadly categorized into four groups. Here is a taxonomy of blockchain privacy-preserving approaches, broken down into four main groups:

1. **Key management and smart contracts Privacy Preservation:** To protect the privacy of smart contracts and the derivation of cryptographic keys, this category includes methods such as Secure Multi-Party Computation (SMPC).
2. **Identity Data Anonymization:** This group of techniques aims to hide the identities of persons participating in blockchain transactions. This covers techniques such as Commitment Schemes, Ring Signatures, Mixing (to hide the identities of the payer and payee), Zero-Knowledge Proofs (ZKPs), and Homomorphic Hiding (e.g., anonymizing coin addresses).
3. **Transaction Data Anonymization:** This group includes methods for safeguarding blockchain transaction contents, making sure that private information like

as exchanged assets and transaction amounts is kept secret. Methods like Differential Privacy, ZKPs, Mixing (for coin anonymization), and Homomorphic Hiding are employed.

4. **On-Chain Data Protection:** This group includes encryption-based techniques designed to protect data stored directly on the blockchain. Some examples of these techniques include secret sharing, attribute-based encryption, and asymmetric encryption.

EVALUATION METRICS

1. **Privacy-Utility Tradeoff:** Finding the ideal balance between privacy and usefulness is one of the main issues with privacy-preserving blockchain systems, particularly in healthcare applications. Sensitive data is protected by privacy mechanisms like encryption and anonymisation, but they may unintentionally make the data less useful for analytics, decision-making, and other uses. Therefore, it is crucial to evaluate the privacy-utility tradeoff such that the privacy-preserving method does not unduly reduce the usefulness of the data. For example, it is crucial in the healthcare industry since, even while patient data needs to be securely stored, an anonymised data collection must, at the very least, benefit diagnoses, medical research, or individualised care. Thus, the key indicator for assessing such a system would be its capacity to maintain privacy and usefulness with the least amount of on the usability of data.
2. **Efficiency and Scalability:** Efficiency and scalability are significant considerations when considering large-scale systems like healthcare blockchain networks for evaluating the deployment of privacy-preserving techniques. Privacy mechanisms like homomorphic encryption and Zero-Knowledge Proofs (ZKPs) are computationally expensive, causing transaction speeds to drop significantly while costs go up. This becomes a bigger issue when dealing with large datasets as is usually the case with healthcare systems that continually generate patient records.
3. **Robustness:** Robustness is the degree to which privacy-preserving blockchain systems are resilient against various attacks, whether it be data breaches or unauthorized access/denial of service attacks. In healthcare where sensitive medical information needs protection, there is the need to develop robust privacy mechanisms against such attacks as a way

of ensuring that the system's trustworthiness and integrity is maintained. Robustness of a system should be determined based on the capability to tolerate several attack vectors without compromising user data confidentiality and integrity. It entails a security evaluation that encompasses both the possible vulnerabilities from cryptographic methods and full security against all types of attacks from both within and outside. A strong system should be able to recover from attacks without losing data or functionality, hence continuing with privacy and service availability.

APPLICATION AND CASE STUDIES

Healthcare

Privacy-Preserving Health Data Sharing This is an area where applications of privacy-preserving methods are highly required in the health industry to ensure safe information sharing within hospitals, clinics, and research institutes. It would allow patients control over their medical history while ensuring that health care providers have access to de-identified data for diagnostics, treatments, and research purposes. Privacy-preserving techniques, including Attribute-Based Encryption (ABE) and Zero-Knowledge Proofs (ZKPs), are used to ensure that the data shared over the network is private and that only authorized people can access specific health information. One of the best examples is blockchain innovation for the administration of electronic wellbeing records (EHR). Here, patients can selectively share their health data with different healthcare providers to ensure privacy while ensuring that the treatment is tailored to the individual's needs. These systems also are designed to ensure compliance with regulations such as GDPR and HIPAA, thereby protecting patient privacy.

Smart Cities:Securing IoT Data

Blockchain technology has the potential to protect data produced by Internet of Things (IoT) devices used in smart city applications. This increase in connectivity of so many devices within urban areas does raise the question of how the collected sensor information, traffic management information, and data from smart meters may be preserved in a non-repudiable manner for future retrieval. Using privacy-preserving blockchain techniques ensures that access or control over IoT data is granted only to legitimate parties being transparent and accountable within the system. Techniques such as Homomorphic Encryption

and Secure Multi-Party Computation can be used in order to keep the sensitive information created by IoT devices private and secret without revealing it to unauthorized parties. For example, intelligent traffic management systems are able to utilize blockchain technology for the purposes of monitoring and analyzing traffic data while maintaining private information about private vehicles, hence sustaining both efficiency of operations and privacy. One major problem that blockchain-based systems face is the protection of data privacy yet ensuring seamless working of smart cities.[4]

CHALLENGES AND LIMITATIONS

Technical challenges for privacy-preserving techniques in blockchain are significant, especially in terms of scalability and computational complexity. As the size of blockchain networks increases and the number of participants grows, it becomes challenging to maintain the efficiency and speed of privacy-enhancing methods. For example, ZKPs and homomorphic encryption require significant computational resources, which can negatively impact the performance of the system, especially in large-scale applications. Scalability is another issue the methods might face because they might not support large scales of data or numbers of transactions, with high costs and delays involved. Ensuring that privacy-preserving mechanisms do not degrade the performance or scalability of blockchain networks is one major challenge.

Ethical and Legal Issues: With privacy-preserving techniques in blockchain comes many ethical and legal issues. From an ethical perspective, it becomes essential that user consent be taken very seriously, such as how fully a user understands what is going to be protected or processed of his or her data in decentralized settings. In legal terms, the integration of privacy-preserving technologies must also adhere to legislations such as information assurance; for instance, the Overall Information Security Guideline executed in the European Association requires severe rules in matters of data privacy and user rights. Obviously, this conflicts with some aspects of blockchain that are thought to be immutable and transparent-perhaps even conflicting with certain aspects of anonymity-boosting methods, such as data anonymization-and clear identification of users and retention policies of their data. The second challenge is the privacy vs. usability trade-off for individual users on the blockchain network.

•Privacy vs. Usability: The major disadvantage of adopting privacy-preserving techniques is to find the balance

between usability and privacy. Even though it enhances the level of privacy through encryption or anonymization techniques, it often tends to make interaction with blockchain systems more cumbersome and complicated for the user. Furthermore, the latency caused or the overhead that privacy techniques might incur for each transaction will inevitably affect the general usability and the overall user experience. An important limitation in the development of practically usable privacy-preserving blockchain solutions is still the achievement of a trade-off between solid protection of robust privacy and smooth user experience.[14]

FUTURE AND RESEARCH DIRECTION

Alignment with Regulatory Frameworks: Current and future blockchain development in healthcare should align with new data protection regulation frameworks. According to the EU Blockchain Observatory and Forum report in 2018, blockchain, although decentralized in principle, presents significant challenges toward its compliance with existing data protection regulations, for instance, General Data Protection Regulation (GDPR) in healthcare. These issues are equally relevant under the “Proposal for a Regulation Concerning the Respect for Private Life and the Protection of Personal Data in Electronic Communications and Repealing Directive 2002/58/EC (Regulation on Privacy and Electronic Communications),” which is intended to replace the ePrivacy Directive as a result of advances in ICT. Although there are efforts in the process of developing privacy-respecting blockchain solutions, it is essential that such systems adhere to the specifications set by the legal instruments, especially in the health sector, as it handles medical data.

- **Quantum-Resistant Cryptography:** Developing quantum-resistant cryptographic algorithms that can provide confidentiality to healthcare data being stored and processed on a blockchain. Traditional cryptographic primitives, based on large integer factorization or elliptic curve public-key cryptography, may become vulnerable to quantum computing. Hence, the demand for designing and implementing quantum-resistant algorithms to protect healthcare data in blockchain environments is growing. There is also a requirement for research that matures into privacy-preserving solutions, such as SMPC, to be used in smart contract execution while maintaining formal verification within healthcare applications.

Usability in Healthcare Blockchain Systems: Usability is an important factor to ensure that end-users, such as health providers and their patients, can manage their privacy quite effectively in blockchain-based systems. Currently, there is a lack of comprehensive, user-friendly solutions for privacy management, especially sensitive healthcare scenarios. For instance, personalized health care services may necessitate data sharing in health care, and automated operations include key recovery and selective data disclosure. Thus, the creation of intuitive tools, which simplify processes, will be important in ensuring the widespread adoption of blockchain in healthcare, where patient consent and privacy management form a key concern.

- **Healthcare Standards Compliance:** As blockchain technology for healthcare applications advances, these health-related solutions must be consistent with current healthcare data handling and privacy requirements. In order for blockchain-based healthcare solutions to be widely adopted and trusted, privacy-preserving features in blockchain applications should be provided in compliance with legal requirements as well as other healthcare sector requirements.

CONCLUSION

Blockchain technology has the potential to revolutionize the healthcare industry’s data administration and exchange processes, addressing long-standing worries about privacy, security, and interoperability. Healthcare providers may make sure that patient data is safely stored and shared in accordance with privacy laws by utilising private blockchains, which offer permissioned access and control over data flow.

The use of cutting-edge privacy-enhancing strategies like encryption, secure multi-party computation (SMPC), and zero-knowledge proofs (ZKPs) further fortifies patient data confidentiality and permits safe collaboration between medical experts without sacrificing confidence.

These include issues with scalability, compatibility with existing systems, and the establishment of consistent standards. In order to maintain compliance with regulations protecting patient privacy, such as GDPR in the European Union or HIPAA in the United States, the healthcare industry must also manage regulatory frameworks.

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Issues and Approaches for Improving the Efficiency of HJBs Performance

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ABSTRACT

Hydrodynamic Journal Bearings (HJBs) are vital components in various industries, ensuring smooth operation of rotating shafts. However, their efficiency is often compromised by challenges such as inadequate lubrication, heat dissipation, cavitation, and material wear. This paper reviews advancements aimed at improving HJB performance and reliability. It focuses on modern lubrication strategies, including nanoparticle-enhanced lubricants like titanium dioxide (TiO_2), which effectively reduce friction, enhance heat dissipation, and stabilize lubricant properties, thereby increasing operational lifespan and reducing maintenance demands. Surface texturing techniques, such as micro-dimples and advanced coatings, are also explored for their ability to enhance lubricant retention and load-carrying capacity. Additionally, innovations in thermal management and structural modifications are discussed for mitigating cavitation and wear. Drawing on recent research and industrial applications, the paper highlights the tangible benefits of these technologies while identifying future research needs. Key recommendations include advancing nanoparticle-infused lubrication systems, improving cavitation and heat transfer models, and developing innovative bearing designs. By addressing these aspects, the study aims to provide a comprehensive understanding of strategies for achieving optimal performance and durability in HJBs, paving the way for enhanced industrial applications.

KEYWORDS : HJBs, Lubrication techniques, Surface texturing, Cavitation.

INTRODUCTION

HJBs are pivotal components in mechanical systems, supporting rotating shafts while minimizing wear and friction. These bearings operate based on hydrodynamic lubrication, where a thin film of lubricant separates the shaft and bearing surfaces, significantly reducing direct contact and frictional losses [1]. Advancements in lubrication technology, surface texturing, and nanotechnology have brought about notable improvements in HJB performance, enhancing their reliability and efficiency [2,3,4].

A critical aspect of HJB performance is the behavior of the lubricant within the clearance space between the journal and the bearing. As the journal transitions from rest to full rotational speed, it achieves steady-state hydrodynamic lubrication, wherein a wedge-shaped lubricant film supports the load and reduces friction. This process involves the gradual development of pressure in

the lubricant film, with distinct phases of static, start-up, and running operation, as illustrated in Figure 1 [3].

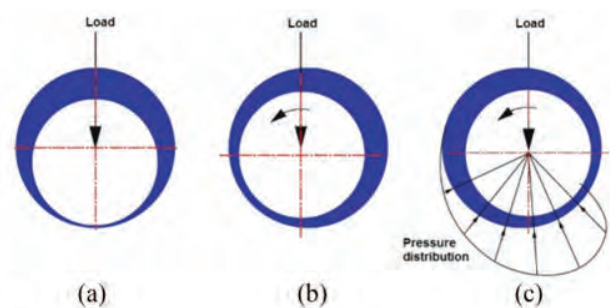


Fig. 1: Mechanism of journal bearing pressure development (a) Static (b) Start-up (c) Running [3]

HJBs find applications across diverse industries, including engines, turbines, marine systems, and

industrial pumps, owing to their ability to handle high loads with minimal friction [6]. Optimizing their performance

is essential for reducing energy consumption, enhancing equipment reliability, and minimizing maintenance costs [5]. Recent studies have shown the potential of advanced lubricants enhanced with nanoparticles like titanium dioxide (TiO_2) to significantly reduce friction, improve heat transfer, and stabilize lubricant properties, thereby extending the operational life of bearings and associated machinery [7,8].

HJBs can be categorized based on their geometric configurations and lubrication methods. Plain bearings rely on a smooth surface and a thin lubrication film to support the shaft, while grooved bearings incorporate surface grooves for enhanced lubricant distribution. Multilobe bearings, designed with multiple lobes, offer improved load distribution, reduced noise, and increased stability, as depicted in Figure 2 [9,10].

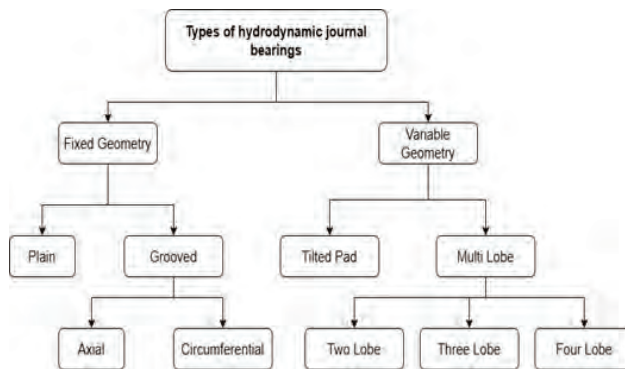


Fig. 2: Flow chart showing general classification of HJB

LITERATURE REVIEW

The performance of HJBs is influenced by various factors, including lubricant properties, surface modifications, structural design, and operating conditions. Research indicates that nano lubricants, particularly those incorporating TiO_2 and CuO nanoparticles, enhance load-carrying capacity, reduce friction, and improve thermal performance, even under elevated temperatures [3,4]. Surface texturing, such as micro-dimple patterns, has also been shown to improve lubricant film stability, reduce wear, and increase load capacity, particularly in high-speed applications [11].

In addition to lubrication and surface enhancements, the structural behaviour of HJBs under operational loads is crucial. Fluid-structure interaction (FSI) analyses have highlighted the effects of structural deformations on bearing stability during dynamic loading. Computational fluid dynamics (CFD) integrated with FSI methods has

further underscored the importance of considering both fluid and structural factors in bearing design [12].

Cavitation, caused by pressure drops that result in vapor bubble formation within the lubricant, is a significant challenge for HJBs, reducing performance and causing surface damage. Numerical modeling of cavitation, particularly in non-Newtonian lubricants, has proven essential for enhancing reliability [13]. Thermal effects also play a critical role, as excessive heat can degrade lubricant properties and reduce efficiency. Nanolubricants, with their superior heat dissipation capabilities, have shown promise in mitigating thermal challenges, especially under high-speed conditions [2,19].

Optimization techniques, such as genetic algorithms and multi-objective approaches, have been widely applied to identify optimal design parameters for HJBs. These methods aim to balance objectives such as minimizing power loss and maximizing load-carrying capacity, resulting in energy-efficient and high-performance bearing designs [14].

This paper aims to consolidate recent advancements in HJB technology and provide a comprehensive overview of modern approaches to improving their efficiency, reliability, and performance.

2.1 Challenges in HJBs Efficiency

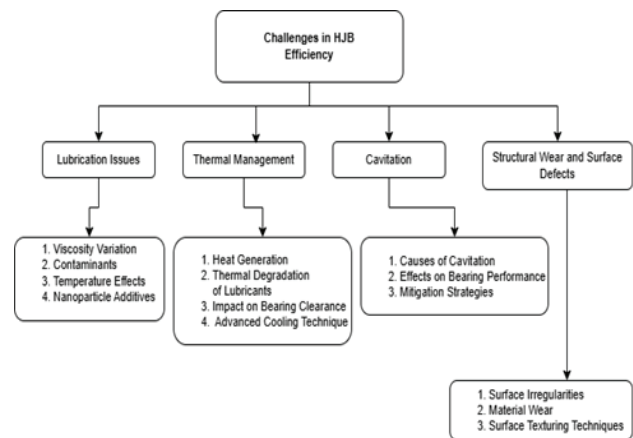


Fig. 3: Challenges in Hydrodynamic Journal Bearing Efficiency

HJBs play a vital role in mechanical systems by supporting rotating shafts and ensuring smooth operation through friction and wear reduction. Despite their importance, several challenges impact their efficiency and durability. Addressing these challenges is crucial to optimizing bearing performance and extending service life. Key issues

include lubrication inefficiencies, inadequate thermal management, cavitation, and structural wear. Each factor significantly influences the bearing's performance under demanding conditions, necessitating focused approaches to mitigate their impact. These challenges are illustrated in Figure 3.

APPROACHES TO IMPROVE HJB EFFICIENCY

Enhancing the efficiency of HJBs is pivotal for ensuring the reliability, energy efficiency, and durability of various mechanical systems. Numerous strategies have been devised, focusing on advancements in lubrication techniques, surface modifications, material enhancements, and structural optimization. A visual representation of these approaches is provided in Figure 4.

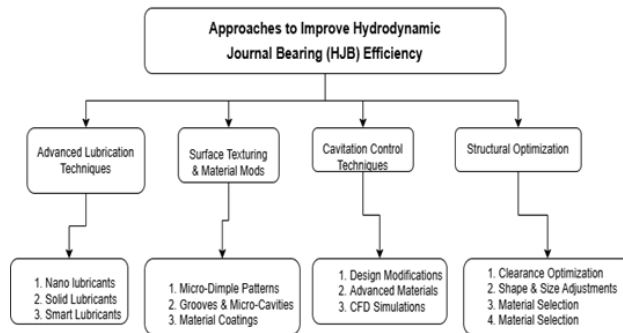


Fig. 4: Shows various approaches used

IMPLICATIONS AND CONCLUSIONS

HJBs are vital components in diverse industries, including automotive and aerospace, due to their ability to minimize friction and wear in rotating machinery. The performance and reliability of these bearings are critical to the efficiency and longevity of the systems they support. However, challenges such as lubrication inefficiencies, thermal management issues, cavitation, and structural wear often limit their optimal functioning.

Future efforts should focus on enhancing thermohydrodynamic and cavitation modeling accuracy, developing more effective optimization techniques, and exploring new material and surface treatment technologies. These advancements will be instrumental in meeting the demands of high-performance and energy-efficient systems.

In conclusion, integrating advanced lubrication technologies, innovative surface textures, and optimized

structural designs offers a robust pathway to improving HJB efficiency and reliability. Continued innovation in these areas will not only enhance the performance of current systems but also drive the evolution of next-generation bearings capable of withstanding increasingly challenging operating conditions.

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Coupled Thermal and Structural Analysis on Different Brake Disc Materials using Finite Element Analysis

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ABSTRACT

Braking is one of the crucial systems of the automobile. Nowadays disc brakes are preferred over drum brakes due to their high heat dissipation capacity. A vehicle possesses kinetic energy when in motion converted into heat when brakes are applied by the phenomenon of friction. This heat results in temperature rise at the interface of disc and pad, as a result temperature stresses are induced in the brake disc. In the present numerical study, coupled analysis of three discs made of gray cast iron (GCI), steel and titanium alloy has been performed. In thermal analysis, temperature distribution and total heat flux is determined and the heat flux are found in the range of 0.00085-0.52711 W/m², 0.001109-0.59592 W/m², 0.0001148-0.29965 W/m² for GCI, steel and titanium alloy respectively. Structural analysis coupled with thermal analysis is performed to determine the total deformation and equivalent stresses. The deformation and stresses obtained are 0.3022 mm & 132.9 N/mm², 0.327 mm & 285.77 N/mm², 0.261 mm & 105.72 N/mm² for GCI, steel and titanium alloy respectively. Based on the results, a suitable material can be selected.

KEYWORDS : Brake disc, Coupled analysis, Thermal, Structural, Heat flux, Deformation, Von-mises stresses.

INTRODUCTION

A lot of researchers have studied the thermal performance of various disc materials. Finite element method is commonly used for performing the analysis. The general methodology used is the preparation of cad model, applying the boundary conditions and determining the desired results. The most common material used is cast iron due to its desirable properties like good thermal conductivity, low weight, and is highly durable, Patil and Chavan [11]. Two materials viz. GCI and cast carbon steel were compared for better performance and high temperature suitability by S. Al Riyami et al. [1] Thermal and structural behavior were analyzed using software. From the study it is concluded that cast carbon steel is superior to GCI when it comes to thermal performance. A similar kind of study was presented by Seelam et al. [2] considering stainless steel and GCI as the brake disc materials. Along with thermal and structural performance, life of the disc was also discussed. GCI compared to stainless steel has longer life and better anti-fade properties.

Lightweight materials were discussed by Chheda et al. [3]. Conventional cast iron is compared with aluminum alloy, Titanium alloy and stainless steel. Analysis using finite element method was carried under similar conditions on these materials. Titanium alloy was found to be the material which can perform better than other materials.

Cast iron of three different grades were used by Belhocine and Asif Afzal [4]. Solid and ventilated discs model were analyzed using FEA. Comparison of aluminium, carbon carbon, stainless steel and titanium alloy was done by Ahmed et al. [5]. Carbon-carbon and titanium alloys have the best performance from a heat dissipation and total deformation point of view. Aluminum composite was investigated for increasing braking efficiency and improving vehicle stability by Balu et al. [6].

For increasing the heat dissipation property and reducing the weight of the disc, aluminum alloy and nanocomposite particles of aluminum were investigated by Sivaprakasam et al. [7]. Nanocomposite aluminum matrix performed better, heat flux was higher, which indicates faster cooling,

and deformation was much less. A study on AISI4140, SS420, and AISI1020 found that SS420 is having superior performance in terms of thermo-mechanical behavior Choudhary et al. [8]. Other than the impact of materials on thermo-mechanical behavior, Mithlesh et al. [9] studied the effect of varying geometrical parameters. Disc plate thickness, rotor thickness, and hole diameters were varied without changing the material and concluded that disc with large-diameter holes performed better. Similarly, Tauviquirrahman et al. [10] proposed geometrical modifications in the disc. Holes and grooves are made on the surface of the disc.

BRAKE DISC AND ITS PROPERTIES

In the present study, a thermal analysis coupled with structural analysis is performed on three different materials viz. GCI, steel and titanium alloy. The thermal as well as structural performance is studied based on the inputs provided. The detailed methodology is shown in the fig. 1. The mechanical and thermal properties for the above said materials are shown in Table 1.

Table 1 Material Properties

Properties	GCI	Steel	Titanium alloy
Density (kg/m ³)	7200	7850	4620
Youngs Modulus (MPa)	110000	200000	96000
Thermal Conductivity (W/m °C)	52	60.5	21.9
Specific Heat (J/kg °C)	447	434	522
Tensile Yeild strength (MPa)	--	250	930
Ultimate tensile strength (MPa)	240	460	1070
Poisson's ratio	0.28	0.3	0.36

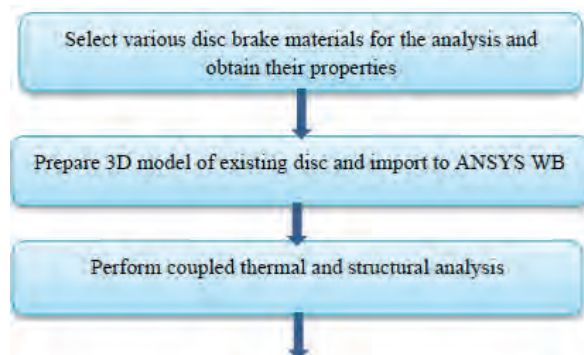


Fig. 1 Methodology Flowchart

A cad model using catia V5 software is prepared as shown in fig. 2

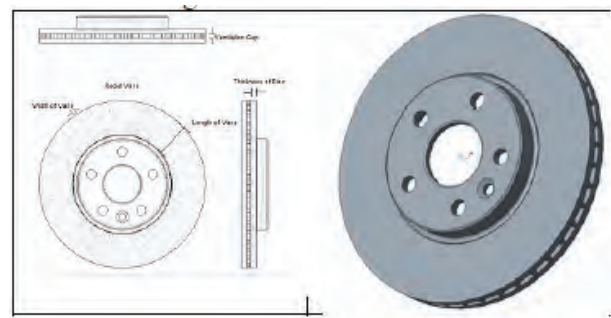


Fig. 2 2D views and 3D model of ventilated disc of disc brake

FINITE ELEMENT ANALYSIS

The 3 D model is then imported to ANSYS Workbench 2024 R1 software for the analysis. Material properties are assigned and then the model is meshed. The meshed model is shown in fig. 3. Element quality and aspect ratio is checked. Tetrahedral elements are used for meshing and total numbers of element are 115,813 while nodes are 181,490.

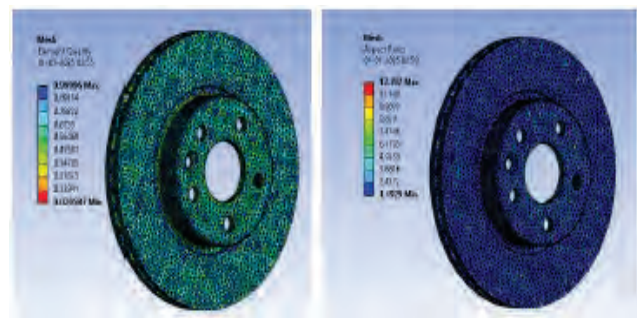


Fig. 3 Meshing of Disc

After meshing is done, steady state thermal analysis is performed on the disc by applying maximum temperature at the rubbing surfaces and providing convective heat transfer coefficient on the remaining surfaces of the disc as shown in fig. 4.

Ambient temperature is considered as 25°C, while on the rubbing surfaces of the disc, a temperature of 210°C is applied. Convection coefficient for air is considered as 230 W/m²°C.

After performing static thermal analysis on all three materials, the temperature distribution and total heat flux is determined which is shown in fig. 5.

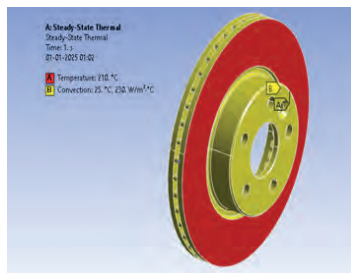
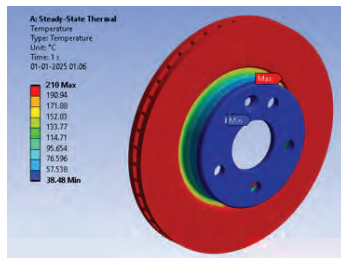
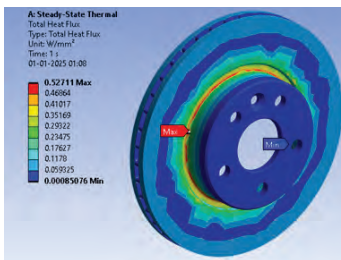


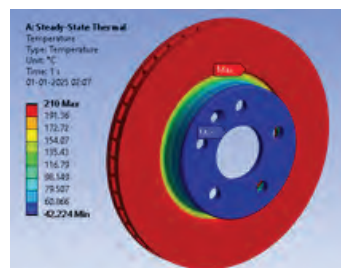
Fig. 4 Steady State Thermal Boundary Condition



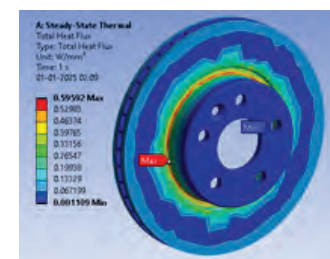
Variation in temperature for GCI



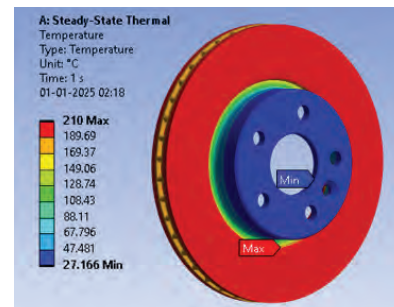
Heat Flux distribution for GCI



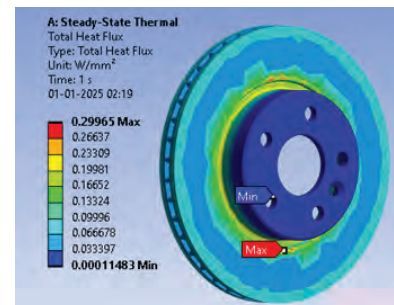
Variation in temperature for Steel



Heat Flux distribution for Steel



Variation in temperature for Titanium Alloy



Heat Flux distribution for Titanium Alloy

Fig. 5 Variation in temperature and heat flux distribution for different materials

The results of steady state thermal analysis are then imported into static structural and coupled analysis is performed. Normal force on rubbing surfaces and angular velocity are applied by fixing all bolt holes as shown in fig. 6.

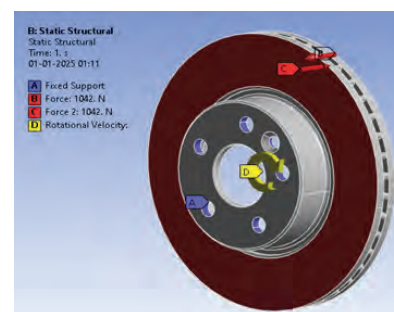
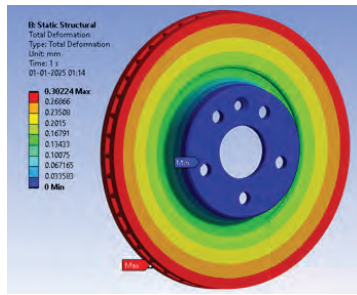
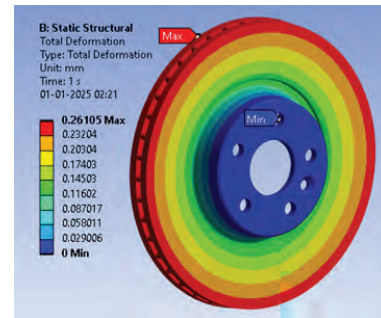


Fig. 6 Static structural Boundary Condition

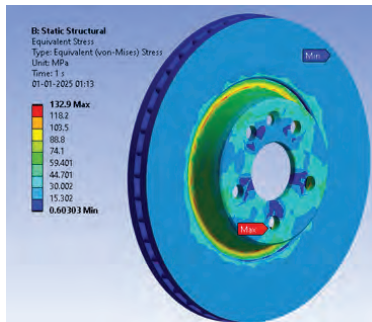
All bolt holes are fixed, a load of 1042 N is applied on opposite faces and angular velocity is taken as 150.7 rad/s. After performing static structural analysis on all three materials, the equivalent stresses and deformation are determined shown in fig. 7



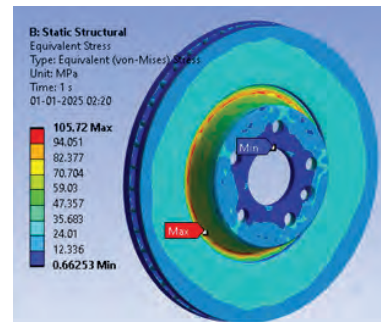
Deformation for GCI



Deformation for Titanium Alloy



Equivalent Stress for GCI



Equivalent Stress for Titanium Alloy

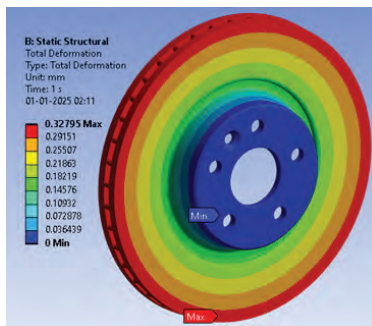
Fig. 7 Total Deformation and Von-Mises stress plots for different materials**RESULTS AND DISCUSSIONS**

The results of coupled analysis are tabulated in the table 2

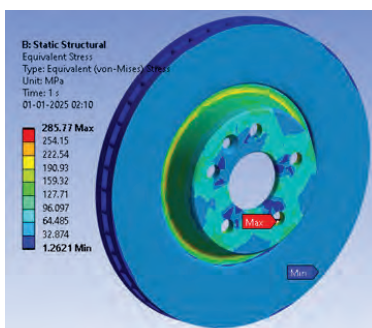
Table 2 Results of coupled analysis

Properties	GCI	Steel	Titanium Alloy
Minimum Temperature (°C)	38.48	42.22	27.16
Min. Heat Flux (W/mm ²)	0.00085	0.001109	0.000114
Maximum Heat Flux (W/mm ²)	0.52711	0.59592	0.29965
Maximum Deformation (mm)	0.3022	0.3279	0.261
Equivalent Stress (MPa)	132.9	285.77	105.72

From the above results, the minimum temperature observed is in titanium alloy but maximum heat flux is recorded in structural steel. This shows that steel can dissipate heat at a very faster rate in comparison to titanium alloy and GCI. So from thermal point of view, steel is superior to GCI iron as well as titanium alloy.



Deformation for Steel



Equivalent Stress for Steel

After coupling the results of thermal analysis with structural analysis, total deformation and equivalent stresses were determined. Table 2 shows the results of the analysis. The results clearly show that, the total deformation in titanium alloy is less compared to other two materials, which is the indication of more structural stability. The maximum value of stress is also less in titanium alloy as compared to GCI and steel.

CONCLUSION

Proper material selection plays a important role in the performance of disc brake. In this study, coupled thermo-mechanical study was carried on three different materials with same geometry and same boundary conditions. Finite element analysis using ANSYS workbench is carried and from the results (table 2) it can be concluded that

- Steel is suitable material as the maximum heat flux (0.59592 W/mm²) is more which indicates better heat dissipation but as its density is more it is heavy compared to other two materials.
- Titanium alloy has more structural stability as compared to other two materials because the observed value of deformation (0.261mm) is less.
- From strength point of view, titanium alloy (equivalent stress is 105.72 N/mm² is less) supersedes the other two materials.
- Though overall weight of titanium alloy is less due to lower density, it is more costly than GCI and steel, which restrict its use.

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Review on Difficulties in CFRP Machining

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ABSTRACT

Carbon fiber-reinforced polymers offer exceptional strength-to-weight ratios and stiffness, making them attractive for high-performance applications, particularly in aerospace and automotive sectors. However, their unique composite structure presents substantial machining challenges, impacting manufacturing efficiency and component quality. This review explores the key difficulties inherent in CFRP machining, focusing on material properties, tool wear, and surface integrity. The anisotropic nature of CFRPs, stemming from directional fiber orientation, leads to variations in material removal rates and cutting forces. Coupled with the abrasive nature of carbon fibers, this anisotropy accelerates tool wear, reduces tool life, and increases machining costs. Delamination, a significant concern in CFRP machining, arises when the layered structure separates due to interlaminar stresses induced during the process. This compromises structural integrity, potentially leading to premature component failure. Matrix materials, often thermosetting polymers, are prone to thermal degradation at the high temperatures encountered in machining, leading to resin decomposition, fiber pull-out, and diminished surface quality. Fiber pull-out weakens the surface, creating stress concentrators. Subsurface damage, such as micro-cracks and delamination, negatively impacts fatigue life and overall performance. This review analyzes these challenges, offering insights into the complex interplay between material properties, tool wear, and surface integrity in CFRP machining.

KEYWORDS : *CFRP, Surface quality, Tool wear, Machining, Fiber pull out.*

INTRODUCTION

Carbon fiber-reinforced polymers have gained significant prominence in high-performance manufacturing companies such as aircraft, shipbuilding, automotive, and wind energy because of their exceptional strength-to-weight ratio, stiffness, and wear resistance. These properties make CFRPs ideal for applications that demand lightweight yet robust materials. However, the unique characteristics.

of CFRPs also present significant challenges in machining processes, particularly milling and turning, which are essential for achieving the desired shapes and dimensions. These challenges primarily revolve around achieving

satisfactory surface quality and maintaining an acceptable tool life, both of which significantly impact the overall manufacturing cost and component performance[1], [2], [3].

The heterogeneous and anisotropic nature of CFRPs, arising from the combination of stiff and brittle carbon fibers embedded in a relatively soft matrix material, leads to complex material removal mechanisms during machining. The fibers, oriented in specific directions to impart strength and stiffness, exhibit varying responses to cutting forces depending on their orientation relative to the tool [4]. This anisotropy results in uneven material removal rates, making it strive to get consistent surface finishes and dimensional accuracy. Furthermore, the frictional nature

of carbon fibers speed up the tool wear, leading to frequent tool changes and increased machining costs.

The milling of CFRPs presents unique challenges owing to the interrupted cutting action and varying fiber orientations encountered during the process. The cyclic loading and unloading of the cutting tool, combined with abrasive fibers, can lead to accelerated tool wear mechanisms such as abrasion, adhesion, and chipping. Moreover, the complex chip formation process in CFRP milling can result in surface defects, such as fiber pull-out, delamination, and surface roughness, which compromise the structural integrity and aesthetic appeal of the finished component. Achieving a smooth surface finish in CFRP milling requires careful optimization of cutting parameters, tool geometry, and tool material [4].

The turning of CFRPs, while involving a continuous cutting action, also faces difficulties related to the anisotropic nature of the material. The varying fiber orientations encountered during turning can lead to fluctuating cutting forces and vibrations, which negatively impact the surface finish and tool life. Delamination, a major concern in CFRP machining, is particularly prevalent in turning operations due to the peeling action of the cutting tool [5]. Delamination of the multilayer structure can lead to a dramatic decrease in the strength and fatigue life of the component. In addition, the heat produced in the turning process can cause a thermal degradation of the matrix material, which causes resin decomposition, fiber pull-out, and consequently diminished surface quality. The only solution to these problems is to use the right cutting tools and conditions. Applications include using composite tools for polycrystalline diamond and for cubic boron nitride due to their hardness and wear resistance. The tools are expensive, therefore the cutting parameters must be optimized for maximum tool life. Thus, the cutting parameters, such as cutting speed, feed rate, and depth of cut have a significant impact on cutting forces, temperature generation, and the friction angle of chip formation that affects both surface finish quality and tool life. Good knowledge of material behavior and tool-workpiece interactions for effective process planning is also a necessity.

This review explores the distinct challenges faced in CFRP milling and turning; the relationship between material properties, tool wear mechanisms and surface integrity. It discusses the effect of variations of fiber orientation, shearing parameters, and tools types on

the machine process and strategies to optimize these parameters to achieve the required surface quality and tools life. We also address the recent developments in cutting tool technology and machining strategies that have been proposed to overcome the difficulties stemming from CFRP machining. An initiative of this review is to contribute a broad view to the CFPP milling and turning challenges, and their numerous possible answers through the easier methods of CFRP shearing, thus encouraging their implementation in capital materials on a wider scale across various sectors.

LITERATURE SURVEY

Machinability Challenges in CFRP Milling

The milling of carbon fiber-reinforced polymers presents unique challenges owing to the heterogeneous and anisotropic nature of the material. The interrupted cutting action and varying fiber orientations encountered during the milling process led to complex material removal mechanisms, tool wear, and surface integrity issues [6], [7].

“One of the primary challenges in CFRP milling is the rapid wear of cutting tools owing to the abrasive nature of carbon fibers. The cyclic loading and unloading of the tool, combined with the high hardness of the fibers, can result in accelerated tool wear mechanisms such as abrasion, adhesion, and chipping. This tool wear directly affects the surface quality of the machined component, as the deterioration of the cutting edge leads to increased surface roughness and dimensional inaccuracies [3].”

“Furthermore, the chip formation process in CFRP milling is complex and can lead to other surface defects including fiber pull-out, delamination, etc., and inconsistencies in surface roughness. Due to the different orientations of fibers, the cutting forces and vibrations vary, causing poor surface quality and the formation of defects in anisotropic materials. In this context, researchers have investigated multiple solutions such as optimizing cutting parameters, tool geometry, and tool materials. The cutting forces, temperature generation, and chip formation process are greatly influenced by the cutting parameters -- cutting speed, feed rate, and depth of cut -- which affect surface quality and tool life.”

Machinability Challenges for CFRP Turning

While the turning of CFRPs involves a continuous cutting action, it also faces difficulties related to the anisotropic

nature of the material. The varying fiber orientations encountered during turning can lead to fluctuating cutting forces and vibrations, which negatively impact the surface finish and tool life.

Delamination, a major concern in CFRP machining, is particularly prevalent in turning operations owing to the peeling action of the cutting tool. This separation of the layered structure can significantly weaken the component and reduce its fatigue life. Furthermore, the heat generated during turning can cause thermally enhanced degradation of the material, forward to resin decomposition, fiber pull-out, and reduced surface quality.

In summary, choosing suitable cutting tools and cutting parameters plays a pivotal role in overcoming the challenges presented by CFRP turning. Material tools like Polycrystalline diamond and Cubic boron nitride are typically chosen due to their remarkable hardness and wear resistance. Nevertheless, the expense associated with those tools calls for optimized processing parameters to ensure maximized tool life. The shearing parameters play important role in the generation of cutting forces and cutting temperature at machining zones.

Strategies for Optimizing CFRP Machining

To dominates the challenges aligned with CFRP machining, researchers have investigated various strategies focused on cutting parameter optimization, tool geometry optimization, and tool materials selection. The first approach involves the utilization of methods such as RSM and MCDM that aid in deciding the best combination of cutting conditions to get the desired output characteristics (surface roughness, tool wear, and material removal rate). Diagnosis of machining conditions. One possible solution is the use of advanced cutting tools and coating to increase tool life and surface integrity. Polycrystalline diamond (PCD) and cubic boron nitride (CBN) tools have provided good results in CFRP machining because of their high hardness and wear resistance. Also used are durable coatings, like titanium nitride or chromium nitride, to enhance thermal and abrasive resistance. "In addition, the application of unconventional machining techniques, such as electrical discharge machining and laser-assisted machining, has been explored to address the challenges associated with CFRP machining. These techniques can help overcome the limitations of conventional machining methods and provide alternative solutions to achieve for the desired surface texture and dimensional accuracy [5], [6]. In conclusion, the carbon-fiber-reinforced polymers

machining presents several difficulties due to the material heterogeneity and anisotropy. Researchers have proposed a number of solutions including, but not limited to, cutting parameters, tool geometry, tool materials, and unconventional machining processes to combat these issues.

DISCUSSIONS

Preventing Tool degradation and Achieving Superior Surface integrity in CFRP machining; becoming efficient and high-quality machining of CFRP necessitates a comprehensive understanding the factors influencing tool wear and surface integrity. This discussion delves into strategies for mitigating tool wear and enhancing surface quality in both milling and turning operations of CFRPs [7], [8].

Tool Wear Mitigation

- **Optimized Shearing Attributes:** The sorted of appropriate cutting parameters, including the "cutting speed, feed rate, and depth of cut, plays a crucial role in minimizing tool wear. "Higher cutting speeds can reduce the contact time between the tool and abrasive fibers, thus decreasing wear. However, excessively high speeds can cause thermal damage to the matrix materials. Lower feed per tooth and DOC can also reduce the cutting forces and tool wear, but at the expense of reduced material removal rates. A balanced approach is essential for optimizing the parameters to achieve a compromise between tool life and productivity.
- **Advanced Tool Materials:** The use of advanced tool materials with high hardness, wear resistance, and thermal stability is essential for extending tool life in CFRP machining. Polycrystalline diamond and cubic boron nitride tools have demonstrated superior performance compared to conventional carbide tools. These materials can withstand the abrasive nature of carbon fibers and maintain their cutting-edge sharpness for longer periods.
- **Tool Coatings:** Applying wear-resistant coatings to cutting tools can further enhance their performance in CFRP machining. Coatings such as titanium nitride, titanium aluminum nitride, and diamond-like carbon can improve the resistance of the tool to abrasion, adhesion, and thermal degradation.

- **Cooling and Lubrication Strategies:** Effective cooling and lubrication strategies are crucial to minimize heat generation and reduce tool wear. Compressed air, cryogenic cooling, and minimum-quantity lubrication techniques can help dissipate heat and reduce friction at the tool-workpiece interface.

Surface Quality Enhancement

- **Cutting insert Geometry:** The geometry of the cutting insert significantly influences the chip formation process and the resulting surface quality. Tools with sharp cutting edges and positive rake angles can promote clean chip removal and minimize fiber pull-out. Specialized tool geometries, such as those with chip breakers or wiper inserts, can further improve the surface finish.
- **Machining Strategies:** Employing appropriate machining strategies, such as high-speed machining or constant engagement angle milling, can enhance the surface quality. High-speed machining can reduce cutting forces and improve surface finish, whereas constant engagement-angle milling can minimize variations in fiber orientation and promote uniform material removal.
- **Post-machining Processes:** Post-machining processes, such as polishing or grinding, can be employed to further refine the surface finish and remove any remaining surface defects. However, these additional processes can increase the overall manufacturing costs and time.

CONCLUSION

Achieving optimal tool life and superior surface quality in CFRP machining requires a multifaceted approach that encompasses optimized cutting parameters, advanced tool materials and coatings, effective cooling and lubrication strategies, and appropriate machining techniques. Further research and development in cutting tool technology, machining strategies, and material characterization are essential for the continuous improvement of CFRP machining processes and the wider adoption of these high-performance materials in various industries.

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Performance Assessment of Friction Stir Butt Welded Aluminum & Copper Joint

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ABSTRACT

Friction stir welding is advanced, green, defect free welding technique. The process is carried at the recrystallization temperature of the base material. This study evaluates the characteristics of aluminum (AA6101) and copper (Cu) weld joints, analyzing the relationship between key process parameters and the resulting mechanical and electrical characteristics. The welding parameters are optimized by Response Surface Methodology (RSM) optimization technique. The experimental runs are performed as per Box-Behnken DOE. The experiments were carried out with tool rotational speeds (TRS) of 840, 1045, and 1300 rpm. The welding speed (WS) was of 25, 45, and 65 mm/min, and tool pin offsets (TPO) of 0.6, 1.0, and 1.2 mm towards the aluminum side. Common welding defects, including cracks, grooving, flashes, and pronounced shoulder marks, were investigated. The tensile strength (TS) of the FSW joints fluctuated from 134 to 162 MPa, while the electrical resistivity (ER) varied between 0.027 and 0.039 $\mu\Omega\text{m}$.

KEYWORDS : Advanced solid-state welding technology, DOE, and RSM.

INTRODUCTION

The environmentally friendly solid-state friction stir welding process has gained significant popularity in modern days due to its various benefits. Pure Copper (Cu) and aluminum (Al) are essential metals usually utilized in the electrical manufacturing because of their excellent strength, thermal conductivity, and electrical properties [11]. But Cu is a dense material and costly; so it is essential to find partial replacement material with Cu to lower the density and cost [3]. Al exhibits similar properties as Cu. Replacement of Cu by Al will give same properties with lower price and density [1]. There are limitations to fusion welding process to produce sound weld joint of Al-Cu due to difference in melting temperature. The development of hard intermetallic composites (IMCs), cracks, and porosity are substantial challenges in the arc welding process [1], adversely impacting the microstructural, mechanical and electrical characteristics of the weld joint [4]. The friction stir welding process effectively addresses these issues and enables the joining of different properties Al-Cu base materials. This welding technique can effectively eliminates the said defects and joins dissimilar Al-Cu because it operates below the recrystallization temperature

[5]. A tool steel material tool with special featured tool pin is used for experimentation. The rotary tool pin is introduced in the neighbouring sides of the weld plates. The tool is fed in the straight line of the raw material weld plate [2]. The frictional contact between the tool steel tool surface and the weld plate surface produces heat. This activity promotes to make soften the plate's material. That improves the plastic deformation of base material. Good collaborating of the material takes place with the rotating tool pin. The rotary pin provides homogenous intermixing [2]. The weld joint performance is considerably affected by the input process variables during welding process. The influence of welding process variables on welded joint performance is analysed in this research work.

EXPERIMENTAL PROCEDURE

The welding process is conducted to join AA 6101-T64 and pure Cu plate of dimensions 150 x 75x 4 mm. The plates were cleaned before welding for removing oxide layer from the surface. A DRO vertical milling machine is used in the process. The base material placement acting a substantial role in the weld joint properties [13]. The tool offset was towards Al material [13]. The tool material was H13 tool steel. The flat shoulder taper pin profile tool was

used for experimentation. Tool shoulder diameter was 20 mm for sufficient heat application; as shown in Fig. 1. The welding strategy for this experimental work is shown in Fig. 2. The tool plunging depth was 0.1 mm. The dwell time was 20s. The experiments were conducted as per the DOE shown in Table 1. Experimental results shown in Table 2 explores the TS and ER output results.

Table 1 Selection of TRS, WS & TPW and their levels

Sr. No.	Input variables	Representation	Stages		
			-1	0	1
1	TRS	X	840	1045	1300
2	WS	Y	25	45	65
3	TPO	Z	0.6	1	1.2



Fig. 1 H13 Tool



Fig. 2 Welding strategy

Table 2. Box-Behkan design matrix and results of TS and ER

Trial run	X	Y	Z	TRS (rpm)	WS (mm/min)	TPO (mm)	TS (MPa)	ER ($\mu\Omega\text{m}$)
1	0	0	0	1045	45	0.9	160	0.030
2	0	1	-1	1045	65	0.6	158	0.031
3	1	1	0	1300	65	0.9	146	0.033
4	0	0	0	1045	45	0.9	160	0.030
5	0	-1	-1	1045	25	0.6	154	0.032
6	0	1	1	1045	65	1.2	160	0.029
7	-1	0	1	840	45	1.2	138	0.027
8	-1	0	-1	840	45	0.6	134	0.029
9	1	0	1	1300	45	1.2	148	0.034
10	-1	-1	0	840	25	0.9	136	0.029
11	0	0	1	1045	45	1.2	162	0.030
12	1	0	-1	1300	45	0.6	142	0.037
13	1	-1	0	1300	25	0.9	142	0.039
14	0	-1	1	1045	25	1.2	158	0.030
15	-1	1	0	840	65	0.9	136	0.027

WELD JOINT SURFACE APPEARANCE

The weld joint surface appearance at the various set of procedure constraints is shown in Fig. 3. Common defect forms in friction stir welding are the exit hole present at the end shown in Fig. 3 (a). The selection of process

parameters plays a noteworthy part in surface defect formation. The WS of 65 mm/min, TRS of 840 rpm, crack defects were observed, as illustrated in Fig. 3. heating and limited softening of the base material result in reduced material flow. The deficient heating and less relaxing of

the base material. It causes less material flow [20]. On some weld joint surfaces groove defect is also observed. It is shown in Fig. 3. A very smooth surface is observed at a TRS of 1045 rpm, a WS of 45 mm/min, and a TPO of 1.2

mm, as shown in Fig. 3 (k). The flash type defect is seen at 1300 rpm due to very high temperature of the process which expel the soft material [21]. The flash type defect formed is shown in Fig. 3 (l, m).



Fig. 3 Joint surface appearance and defects formed during the process

RESULT DISCUSSION

The TS and ER of the weld joints were analyzed to evaluate the influence of process parameters. This analysis provides insights into how variations in these parameters influence performance of the weld joints.

Tensile strength

The weld joint strength was evaluated through tensile testing using ASTM E8 samples on a UTM machine. The impact of process parameters on TS is illustrated in Fig. 4.

Consequence of TRS

The significance of TRS is presented in Fig. 4. Lower

strength is observed at 840 rpm. Insufficient material flow causes the low TS of the weld joint. Strength of the weld joint increased with higher rotational speeds, reaching 162 MPa at 1045 rpm. Enhanced intermixing at this speed resulted in a stronger weld joint [13]. Once the speed increased to 1300 rpm further, the strength decreased. The reason for that was more heat generation at longer period of contact. This widely stimulates the thickening of IMCs in the SZ [7]. The TS was reduced with increased in the IMCs in the weld zone [13].

Consequence of welding speed

Low TS was seen at a WS of 25 mm/min due to

excessive heat generation, leading to the development of intermetallic compounds (IMCs) that weakened the weld joint. Additionally, differences in flow stresses caused improper mixing, while turbulent material flow in the stir zone further reduced joint strength. The effect of WS is illustrated in Fig. 4. An improvement in TS was noted at 45 mm/min, attributed to a fine grain structure and normalized flow patterns. However, increasing the WS to 65 mm/min resulted in lower TS due to inadequate mixing of the base material and reduced plastic deformation.

Consequence of tool pin offset

The effect of TPO on TS is illustrated in Fig. 4. Lower TS was observed at a 0.6 mm TPO, attributed to poor connection and the formation of void defects. Due to lower offset, more copper atoms in the stir zone produces IMCs which lowers the strength [15]. The sufficient tool offset from 0.9 to 1.2 mm results in improved TS. Also, less amount of IMC formation takes place which increases the TS [14, 15, 16].

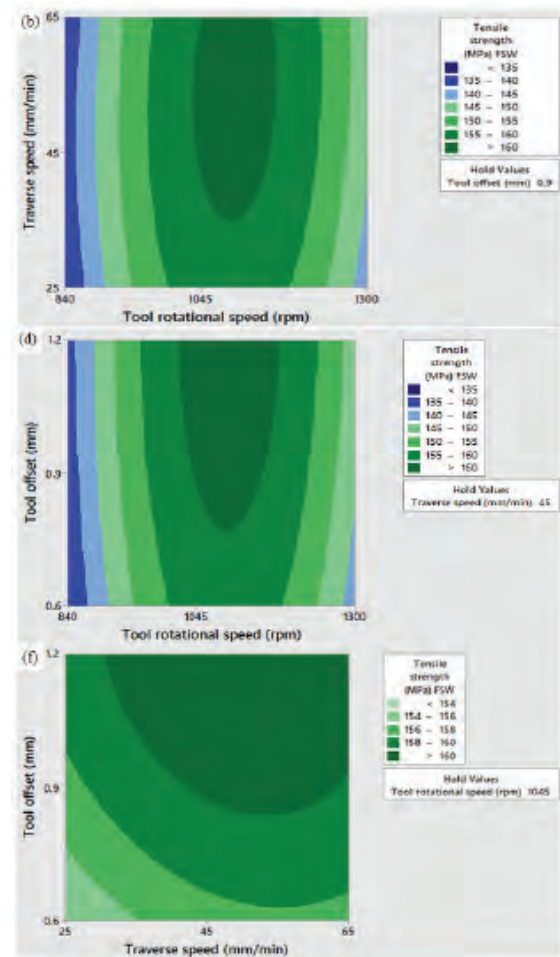
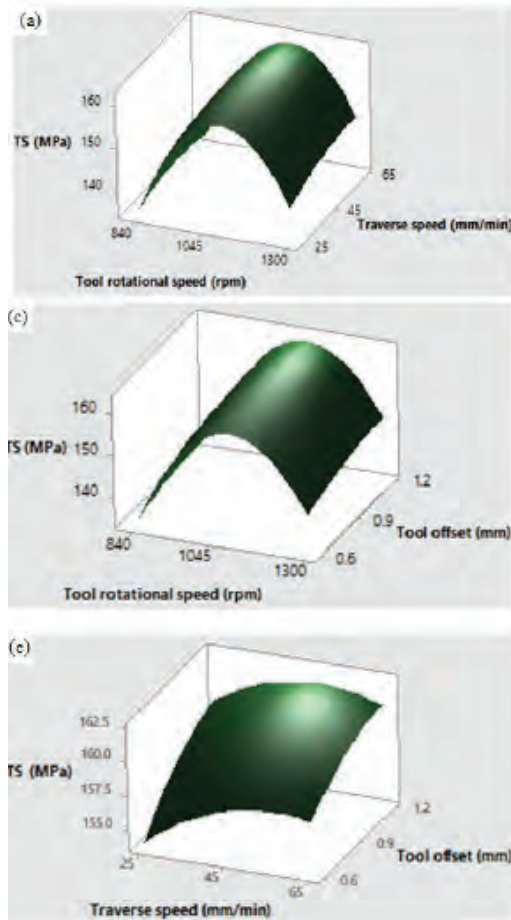


Fig. 4 Surface and contour plots for TS

Electrical resistivity measurement test

ER was measured in the range of 0.027 to 0.039 $\mu\Omega\text{m}$. The resistivity is influenced by factors such as heat input, material mixing, and the construction of IMCs, all of which significantly affect the electrical performance of the weld joint. The resistivity performance is illustrated in Fig. 4.

Significance of TRS

The weld joint's performance in terms of resistivity is presented with higher resistivity observed at 1300 rpm. At this speed the temperature rises which produces thick IMCs. These IMCs increases the resistivity [12]. The minimum resistivity was observed at 840 rpm, where the lower TRS resulted in reduced heat input. This lower heat input contributed to the lowest resistivity The lower heat input produces lower IMCs which lowers the resistivity significantly [12].

Significance of welding speed

WS is a critical parameter influencing resistivity, as it regulates the heat contribution during the welding procedure. At a WS of 25 mm/min, higher resistivity was observed due to the construction of thicker IMCs [12]. In contrast, increasing the WS led to lower resistivity, attributed to reduced heat input and thinner IMC layers.

Significance of tool pin offset

Higher resistivity is seen at lower tool pin offset. At low tool pin offset of 0.6 mm, higher amount of copper atoms mixes that increases the amount of IMCs formation which increases the resistivity. When the tool was shifted towards Al side at 1.2 mm, the IMCs formation reduced which resulted in lower the resistivity.

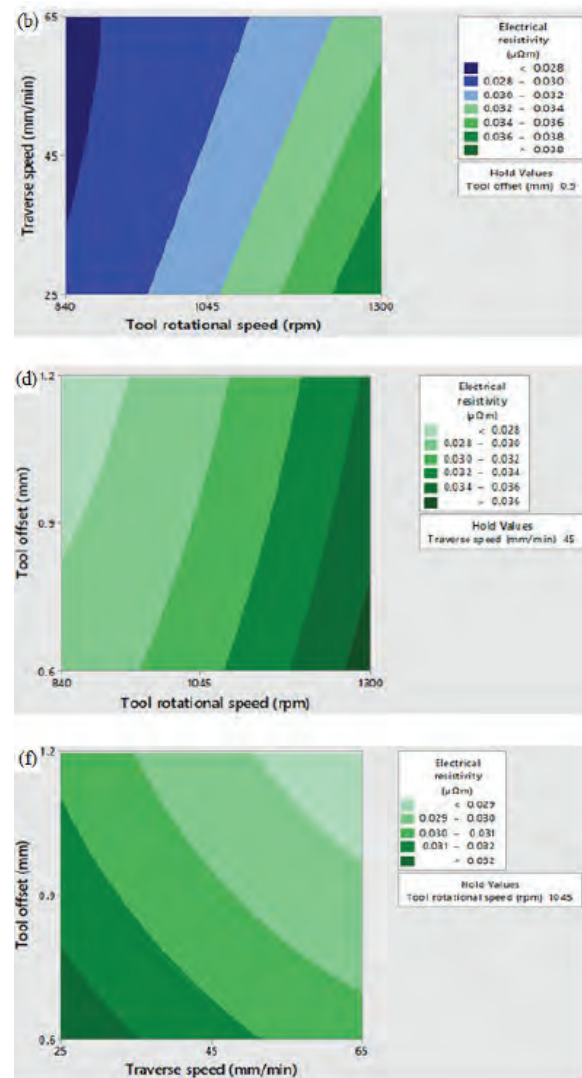
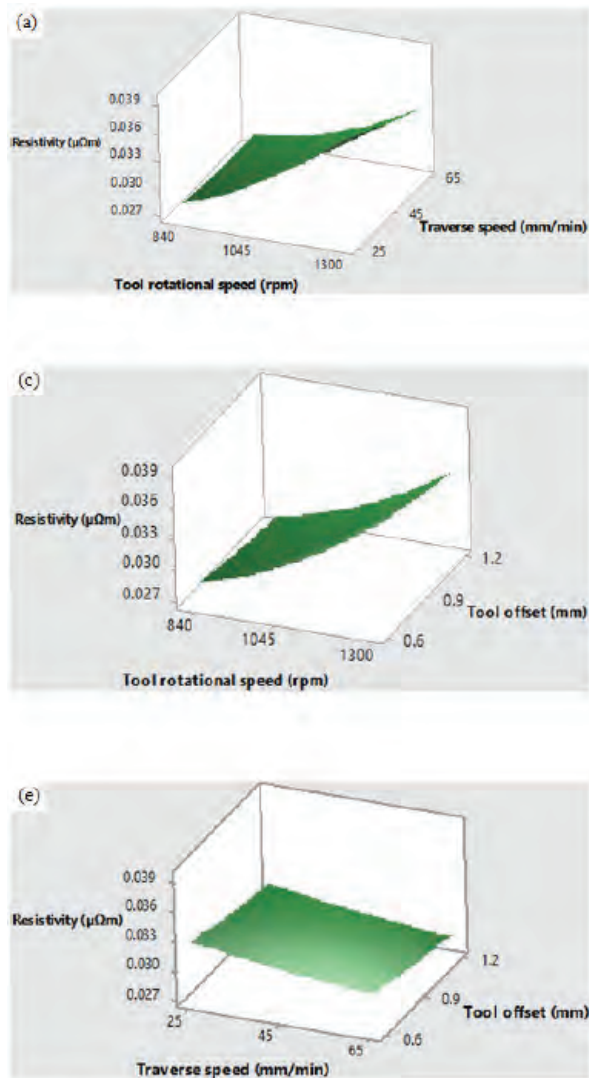


Fig. 5 Surface and contour plots for ER of the weld joint

CONCLUSIONS

- (1) High strength AA 6101 and pure Cu weld joint is prepared.
- (2) All the process parameters are significant for surface appearance.
- (3) The placement of the base material plates is key factor for sound weld joint formation.
- (4) Both TRS and WS show an impact on sound welded joint formation.
- (5) The TPO also plays a crucial part in both solid-state weld joint strength and ER.

- (6) The TS obtained ranged from 134 to 162 MPa.
- (7) The ER measured ranged from 0.027 to 0.039 $\mu\Omega\text{m}$.

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A Comprehensive Study of Defect Analysis and Reduction in Gravity Die Casting

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ABSTRACT

This study decisively tackles the challenges of gravity die casting, specifically focusing on the production of brake caliper brackets for two-wheeler vehicles. We are committed to addressing the critical threats to quality, productivity, and safety that arise from casting defects such as shrinkage, unfilling, and cracks. By employing Ishikawa diagrams, Pareto charts, and numerical simulations, our investigation will identify root causes and propose innovative, actionable strategies for mitigation. Looking ahead, our emphasis on optimizing gating systems, mastering precise temperature control, and refining mold designs will significantly reduce rejection rates. The expected findings will highlight the essential role of advanced monitoring and defect analysis tools in enhancing manufacturing efficiency and competitiveness. As the industry approaches the goal of achieving defect-free castings, this research is poised to usher in a new era of innovation and quality assurance in gravity die casting.

KEYWORDS : *Automotive component, Casting defects, Process parameter, Shrinkage.*

INTRODUCTION

Casting, an ancient metal production method, allows for intricate shapes and finds extensive use in automotive, agriculture, defense, railways, and machinery manufacturing due to its capability of complex geometries for high-speed production. Foundry practices process nearly all engineering materials, creating complex shapes that are not viable through other methods due to difficulty or cost. Aluminum-based alloys are extensively utilized in automotive industries due to their lightweight nature, good corrosion resistance, and exceptional strength-to-weight ratios [1-5]. To achieve optimal functionality, cast products must meet diverse performance requirements without fail, regardless of industry. Defects in casting encompass deviations from prescribed quality standards due to inconsistencies or imperfections, impacting design, service, and customer expectations. Casting defects persist despite controlled conditions and skilled labor, affecting overall manufacturing output, and understanding parameters like materials, gating design, and pouring conditions for flawless casting. Ongoing research focuses on mold size, process parameters, riser, and gating mechanisms to enhance quality [6-8]. Complex process

parameters heighten vulnerability, requiring significant intervention for defect-free cast product manufacturing. Defects are inherently possible during casting.

Among the various casting processes, in gravity die casting (GDC), molten metal is filled into metallic molds by gravity. The method uses a preheated two-part mold into which molten metal, often non-ferrous alloys like aluminum, is poured. Gravity aids metal flow into the mold without external forces. In the mold cavity, the molten metal precisely takes the shape of the cooling and solidifying process. This casting technique is highly regarded for its ability to produce accurate and high-quality parts with refined surface finishes. Due to its ability to make precise dimensional parts in large quantities, it is particularly popular with industries such as automotive and aerospace. Currently, many casting industries are facing numerous challenges in minimizing casting defects and optimizing process parameters. Manually identifying and resolving these defects is both time-consuming and expensive.

An esteemed manufacturer that specializes in braking components for two- and three-wheeler automobiles has

been operational since 2012 and is located in Pune MIDC, Maharashtra. While using the gravity die casting process, the company encountered a rejection rate of 35.50% for rear wheel brake caliper brackets (RWBCBs) for two-wheelers due to casting defects. These casting defects, including shrinkage, unfilling, and cracks, are undermining the structural soundness of the RWBCB, thereby affecting the brakes' performance and safety of automobiles. The company is concerned that its reputation and productivity in the automotive industry might be affected by its persistently high rejection rate.

This study addresses the critical challenges of casting defects in GDC, a vital process for producing high-quality components. Despite its efficiency and precision, GDC faces issues like shrinkage, cracks, and unfilling that compromise quality and safety. Identifying the root causes of these defects is essential for effective solutions. Optimizing mold designs, refining process parameters, and leveraging advanced simulations empower manufacturers to reduce rejection rates and enhance casting reliability. This review analyzes common casting defects and provides actionable insights for mitigation, aiming to establish defect-free casting practices that enhance productivity, cost efficiency, and sustainability in manufacturing.

LITERATURE REVIEW

In GDC these defects often arise due to inadequacies in material selection, gating design, pouring conditions, and other critical process parameters. Several research has used Ishikawa diagrams, simulation analysis, experimentation, and mathematical models to address these challenges. These models have been integrated into software solutions to streamline defect identification and resolution processes. Controlling factors are crucial to ensuring quality products in the casting process. Despite this, frequent defects underscore their importance, driving efforts to identify causes, reduce defects, and improve the process. The manufacturing process was supported by numerical simulations using specialized software, enabling manufacturers to reduce casting flaws and improve manufacturing processes.

Ghubade and Kumar, stress the consequence of defect-free casting for economic growth. Their study analyzes casting defect causes and explores prevention methods, recognizing their economic implications [9]. Gandhi et al. analyzed how mechanical vibration affects aluminum alloy properties during gravity die casting, studying

changes in mechanical properties and microstructure [10]. Malhotra and Kumar highlighted the significance of analyzing process parameters in gravity die casting to reduce casting defects [11]. Prajapati et al. mitigated hand wheel casting shrinkage defects using Fishbone diagrams and ADSTEFAN simulation, achieving economic benefits for foundries [12]. Mehta et al. studied casting process complexities leading to defects despite available remedies and software. This study highlights the gap between foundry practices and tools for defect-free casting [13]. Sithole et al. used process knowledge to reduce sand casting defects and enhance metal casting competitiveness. Process knowledge boosts sand casting competitiveness - optimize processes, cut costs, increase efficiency, and produce quality metal casts. [14]. Siekański and borkowski used quality tools (Pareto, Ishikawa) to address casting defects. High temperatures reduced porosity, air blasting minimized mold issues, and sand mulling resolved buckling and porosity problems [15]. Chandna and Chandra scrutinized crankshaft defects, using Pareto diagrams and cause-and-effect analysis. Several corrective measures were proposed to reduce rejection and rework rates significantly [16]. Alena et al. analyzed casting defects across casting types over a year, focusing on sand inclusions. Throughout production phases, defects were observed, and quality tools were applied to improve quality [17]. Joshi and Jugulkar, studied a foundry's manual casting operations, identifying defects like mold shifting, crushing, and porosity. Analysis via Pareto and cause-and-effect diagrams aimed at improving quality and productivity [18]. Kumar & Tiwari's study uses X-rays, cause-effect diagrams, and Pareto charts to evaluate defects in aluminum wheel production. In addition to determining optimal molten metal temperatures, they investigate the influence of hydrogen on stalk changes [19]. Vaseem and Khuran reduced aluminum casting defects using quality tools: X-ray inspections, Pareto charts, and Fishbone diagrams. Defects such as shrinkages, inclusions, porosity, and cracks are attributed to factors like stalk changes and molten metal temperature [20]. Chelladuria et al. discussed the importance of root cause analysis to improve a foundry's operations, thereby reducing the impact of casting defects on quality and productivity [21]. Czerwińska and Piwowarczyk address rail vehicle casting defects using quality tools for diagnosis and prevention. Quality improvement requires continuous monitoring, analyzing common defects, and correcting causes such as low metal temperatures and incorrect mold settings [22].

Bharambe et al. analyzed HPDC defects in aluminum cylinder blocks, identifying major issues such as cold shut, shrinkage, soldering, stain, crack, and warpage impacting 80% of rejections and proposed solutions to enhance casting quality [23]. Hejne et al. examined defects in die castings through Ishikawa and Pareto-Lorenz diagrams, emphasizing parameter deviations affecting aerospace and automotive product quality, and providing practical industry insights for improvement [24].

The literature clearly shows that casting defects remain a significant challenge in manufacturing, impacting quality, productivity, and economic performance. Researchers effectively use tools like Ishikawa diagrams, Pareto charts, and numerical simulations to identify root causes and implement strong corrective measures. Optimizing process parameters and enhancing mold and gating designs are crucial for reducing shrinkage, porosity, and cracks. Successful case studies demonstrate the integration of defect analysis with production trials, leading to marked improvements in casting quality. Given the complexity of casting processes, continuous monitoring, and advanced modeling are essential for achieving defect-free castings and maintaining competitiveness in the industry.

CASE STUDY

Automotive components, such as brake caliper brackets, cylinder heads, cylinder head covers, cylinder blocks, bed plates, transmission housings, oil pans, and cam covers are produced in a foundry using various state-of-the-art production processes, including gravity die casting. The identified foundry industry confidently pursues the goal of manufacturing top-quality auto components. While challenges like brake caliper bracket casting rejection are present, the foundry is determined to deliver innovative solutions quickly and efficiently, demonstrating an unwavering commitment to excellence. Through rigorous research and a steadfast determination to succeed, the foundry is pushing the boundaries of what's possible in automotive component manufacturing.

Production of rear wheel brake caliper bracket (RWBCB): Automotive components, such as brake caliper brackets, cylinder heads, cylinder head covers, cylinder blocks, bed plates, transmission housings, oil pans, and cam covers are produced in a foundry using various state-of-the-art production processes, including gravity die casting. The identified foundry industry strives to develop top-quality auto components to achieve this goal. Despite facing

significant challenges, such as brake caliper bracket casting rejection, the foundry is committed to finding innovative solutions and implementing them efficiently and quickly. Through rigorous research and a steadfast determination to succeed, the foundry is pushing the boundaries of what's possible in automotive component manufacturing.

A quality check report provides a detailed account of the casting components that have been rejected, along with their respective defects such as shrinkage, blowholes, unfilling, rubbing, cracks, inclusions, and die coat defects. This report also calculates the rejection percentage for rare wheel brake caliper brackets over a specific period. To identify the major contributing defects, the quantity of each defect is divided by the total rejections. A casting defect caused a 35.05% rejection rate for the rear wheel brake caliper bracket in the past year.

Table. 1. Percentage contribution of defects in casting

Defects	Qty. of Rej.	% of Rej.	Cumul. % of Rej.
Shrinkage	8958	34.37	34.37
Blowhole	7066	27.11	61.48
Unfilling	3132	12.02	73.50
Rubbing	1954	7.50	81.00
Diecoat	1844	7.07	88.07
Crack	1417	5.77	93.84
Inclusion	576	2.21	96.05
Damage	439	1.68	97.73
Pinhole	263	1.01	98.74
Other	415	1.26	100

Pareto Chart Analysis: Pareto Analysis is a powerful technique that enables us to make data-driven decisions and identify significant defects that hinder our performance. Our ability to achieve remarkable results and drive growth can be enhanced if we focus on the attributes with the greatest impact. The Pareto principle reminds us that small changes can make a big difference, and by carefully analyzing the data, we can identify the key drivers of success. The Pareto chart helps us visualize the primary nonconformance casting defects and provides a clear path toward improvement. Figure 1 presents a Pareto analysis of the rear wheel brake caliper bracket during the study period.

According to the 80:20 concept, Pareto analysis prioritizes defects with the highest occurrence rate. In this case,

'Shrinkage' defects were identified as the top priority, followed by Blowhole, Unfilling, Rubbing, Diecoat, Crack, and Inclusion. To address the Voice of the Customer (VOC) and the voice of the business, this study focused on Shrinkage, Unfilling, and Crack defects. Figure 2 shows the photographs of shrinkage, unfilling, and crack defects in the RWCBC. These defects were identified as the most critical issues needing immediate attention to improve the quality of the rear wheel brake caliper bracket.

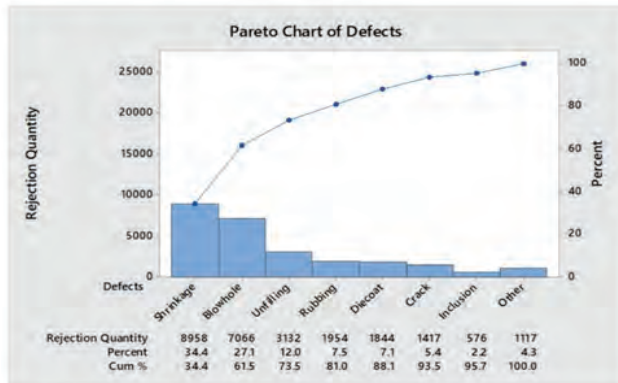


Fig. 1 Pareto analysis of RWCBC defects



a) Shrinkage b) Unfilling c) Crack

Fig. 2 Defects in RWCBC casting

RESULTS AND DISCUSSION

Conducting a comprehensive defect analysis is essential for guaranteeing the success and superior quality products. By identifying the potential causes of defects, manufacturers can take corrective measures and improve the overall quality of their products. Multiple defects and their causes can be studied with an Ishikawa diagram. This diagram, along with effective techniques like brainstorming and group discussions, is essential for thoroughly identifying all causes and effects of defects. By paying attention to insufficient molten metal feeding, gating design and dimensions, total solidification time, local solidification time, mold temperature, pouring temperature, and improper pouring, manufacturers can prevent defects

and ensure that their products meet the highest quality standards.

Cause of Shrinkage in RWCBC: As materials cool down, they tend to contract, which is known as shrinkage in casting. However, this process holds the key to creating objects that meet the desired specifications. The final product must accurately reflect the desired design, so manufacturers must consider shrinkage when designing molds and casting objects. Careful planning can lead to beautiful objects made from molten materials. Figure 3 confidently showcases the Ishikawa diagram of shrinkage, effectively displaying the contributing factors that lead to the observed shrinkage.

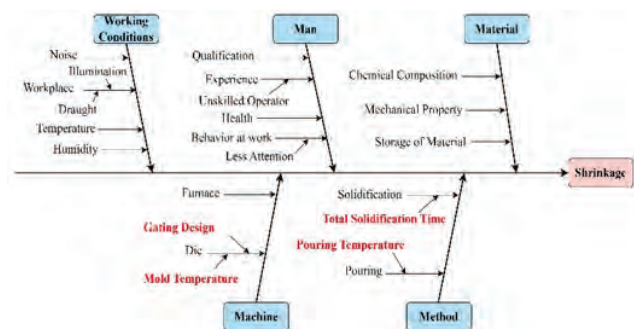


Fig. 3 Ishikawa diagram of shrinkage defect in RWCBC

Through careful observation and analysis of the gravity die-casting process in the industry, we can pinpoint the various factors that lead to shrinkage defects in RWCBC components as follows:

- The gating system ensures smooth metal flow into the mold cavity, eliminating turbulence, defects, and uneven metal distribution. A well-designed gating system is the cornerstone of high-quality castings, inspiring awe and admiration.
- Maintaining a precise pouring temperature range tailored to the specific alloy and casting geometry ensures uniform solidification and minimizes shrinkage defects. Excessive pouring temperature leads to rapid solidification and excessive shrinkage, while too low a pouring temperature results in poor metal flow and incomplete mold cavity filling.
- Total solidification time depends on various factors, linked to the precision of the casting process. In addition to alloy composition, casting geometry, mold design, and cooling rate, other factors affect the total solidification duration.

- Mold temperature impacts solidification rate, cooling uniformity, microstructure, hot spot prevention, and thermal stress reduction. High-quality castings are produced when mold temperatures are tightly controlled, minimizing shrinkage defects.

Balancing pouring temperature, cooling rate, mold temperature, well-designed gating system, and alloy characteristics is essential for uniform solidification and minimizing shrinkage, ensuring precision in the casting process.

Cause of Unfilling in RWBCB: An unfilling defect occurs when the molten metal fails to fill the mold cavity before solidifying, leading to voids, incomplete features, or insufficient material in parts of the casting. Figure 4 confidently showcases the Ishikawa diagram of unfilling, effectively displaying the contributing factors that lead to the observed unfilling in the casting.

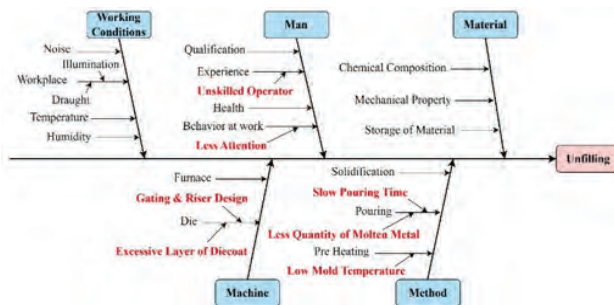


Fig. 4: Ishikawa diagram of the unfilling defect in RWBCB

The various factors that lead to unfilling defects in RWBCB components are as follows:

- Inattentive or unqualified operators lower process efficiency, leading to unfilling defects.
- Slow pouring speeds and insufficient molten metal hinder complete mold filling, while low mold temperatures reduce metal flowability, causing incomplete filling in intricate areas.
- A well-designed gating system ensures smooth metal flow, preventing turbulence and air entrapment.
- Proper riser placement and sizing ensure molten metal fills the mold before solidifying; incorrect designs lead to incomplete filling.

Cause of Crack in RWBCB: A crack defect in gravity die casting refers to surface or internal fractures in the casting, caused by internal stresses exceeding the material's strength during solidification or cooling. Figure 5 showcases the

Ishikawa diagram of crack, effectively displaying the contributing factors that lead to the observed crack in the casting.

The various factors that lead to crack defects in RWBCB components are as follows:

- Thermal gradients caused by uneven cooling can create internal stresses, leading to cracks.
- Inadequate feed metal during solidification can lead to shrinkage stresses, which may cause cracking.
- Sharp corners and abrupt transitions in the mold design can concentrate stress, increasing the risk of cracks.
- Poor control of pouring temperatures, mold temperatures, and cooling rates can result in rapid cooling or excessive thermal gradients, contributing to crack formation.

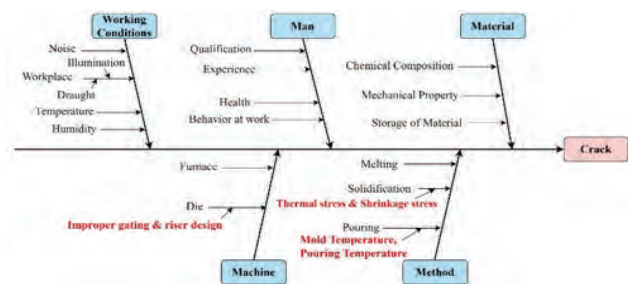


Fig. 5 Ishikawa diagram of crack defect in RWBCB

Remedies to control the casting defects in RWBCB

- Gating System Optimization: Design an effective gating system for smooth metal flow, preventing turbulence, air entrapment, and uneven distribution. This reduces shrinkage, unfilling, and cracking defects.
- Precise Pouring Temperature Control: Maintain the ideal pouring temperature for each alloy to ensure uniform solidification, and minimize shrinkage defects and the risk of incomplete filling or cracking.
- Skilled Operators and Process Control: Employ qualified operators who adjust pouring speed and metal levels for complete mold filling, ensuring smooth solidification, and reducing defects.
- Proper Mold Temperature Management: Maintain consistent mold temperatures for uniform cooling, preventing thermal gradients that could cause cracking or shrinkage.

- Sufficient Feed Metal and Riser Design: Ensure a reliable feed metal supply to avoid shrinkage stresses, with careful riser placement to fill the mold and prevent defects.
- Refined Mold Design: Smooth transitions and rounded corners in the mold minimize stress concentrations and prevent cracking from thermal gradients.
- Control of Cooling Rates: Optimize cooling rates for uniformity, preventing excessive thermal gradients that can lead to cracks while minimizing shrinkage and ensuring complete filling.

CONCLUSIONS

This study highlights the challenges of gravity die-casting processes, revealing a golden opportunity to tackle persistent casting defects! It drives home the urgent need for cutting-edge gating systems, impeccable temperature control, highly skilled operators, and innovative mold designs. By strategically addressing issues like shrinkage, unfilling, and cracks, manufacturers can unlock a pathway to dramatically enhanced quality, slashed rejection rates, and boosted productivity. Utilizing advanced defect analysis tools and continuous monitoring is crucial for achieving flawless castings and excelling in the industry.

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Selection of Parameters for Non-Traditional Machining Processes

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ABSTRACT

In the realm of material cutting, the constant evolution of technologies and techniques poses significant challenges in managing process parameters for diverse materials. This study delves into the optimization of process parameters for the NTM process i.e. Abrasive water jet machining (AWJM), specifically tailored for cutting toughened glass. The NTM machine setup offers flexibility in adjusting process parameters to cater to various materials and cutting requirements. To achieve the desired outcome, a comparative analysis of five distinct settings is conducted, evaluating their impact on key product characteristics such as surface finish, cutting time, cost, and thickness. The process parameters, including stand-off distance, pressure, mass flow rate, traverse rate, and cutting orientation, need to be optimised which is very crucial to meet industry requirements. To this end, optimal parameter settings are determined for the NTM process, multi-criteria decision-making methods are employed, ensuring a balance between competing factors and yielding the best possible results.

KEYWORDS : *Process parameters, NTM, Multi-criteria decision-making methods.*

INTRODUCTION

The utilization of Abrasive Water Jet Machines (AWJM) has revolutionized the cutting of diverse materials, including metals, steels, aluminium, and iron sheets, as well as modern materials like plastics, polyvinyl chloride sheets, and toughened glass. This research explores the application of AWJM in cutting toughened glass, with a focus on preserving the physical as well as chemical properties of the material. The widespread commercialization of AWJM can be attributed to its numerous advantages, particularly in economical manufacturing, where it excels due to its minimal impact on the microstructure of the surface. Unlike traditional machining processes, AWJM has emerged as a highly competitive method, especially for cutting hardened materials, which have been challenging to machine over

the past two decades. The cutting operation involves a high-velocity stream of water combined with an abrasive slurry, comprising materials like aluminium oxide and iron particles, which significantly enhances the cutting efficiency and material removal rate. Furthermore, factors such as particle velocity, concentration, and spindle traverse speed, and spindle angle of striking plays a crucial role in determining the material removal rate of the overall cutting process. By optimizing these parameters, AWJM can be effectively employed to cut toughened glass without compromising its properties, making it an attractive option for various industrial applications.

Abrasive Water Jet Machining (AWJM) process uses a high-velocity stream of water, along with abrasive particles, to strike the work piece surface, resulting in erosion and material removal. This phenomenon enables the AWJM

process to cut a variety of materials without modifying their thermal properties. Notably, the cutting forces involved in AWJM are significantly lower compared to other non-traditional machining processes. The precision of the AWJM process is further enhanced by automated mechanisms that control the position of the pressure jet, while a robotic arm ensures accurate movement along a predetermined path, minimizing positional errors. The versatility of AWJM has led to its widespread adoption in various industries, including aerospace, automotive, and electronics. In the aerospace sector, AWJM is used to cut complex materials like titanium, which are highly sensitive to microstructural changes caused by heat generated during machining. The process is employed in the manufacture of critical components, such as military aircraft parts, engine components, satellites, and panels. Additionally, AWJM is used in the automotive industry to produce components like headliners, car bumpers, door panels, and windshields, showcasing its ability to precision-cut a diverse range of materials.



Fig. 1: AWJM Set up and Parts

The texture of a surface has a significant impact on its interactions with the surrounding environment. In the context of mechanical components, surface topology is a crucial factor in determining their performance and longevity. The presence of surface irregularities can create vulnerabilities that may lead to the formation of cracks or corrosion, ultimately affecting the component's overall functionality. As a result, surface roughness is a key

consideration in the design and manufacture of mechanical components, as it can influence their behaviour and performance in various environments.

[1]. AWJM process has found several industrial applications, especially for profile-cutting or contouring and in processing materials which are difficult to cut such as Polyvinyl chloride, Plywood, toughened glass, ceramics and marbles. The distortion and severity of surface breakdown are dependent on the applied pressure applied by the fluid. The process can be chosen in accordance with the product's specifications or also with additional concerns of various criteria of the product i.e. build time and surface finishing, material elongation and geometrical accuracy, etc. Applying proper decision support system for process selection, the higher accuracy and reliable output can be obtained. The literature survey discussed about the study carried out by the previous researcher for abrasive water jet machining and its process parameters. The process parameters selection is a complex process, where various machining parameters must be defined and calculated for different materials.

M. A. Azmir et al. [2] Researchers have investigated effect of process parameters on surface roughness in Abrasive Water Jet Machining (AWJM) for various materials. For instance, Boud, F et. Al. [3] employed the Taguchi method to analyse the effect of process parameters on surface roughness while machining glass fibre-reinforced epoxy resin and performance of surface roughness (Ra) in terms of AWJM cutting parameters was predicted by preparing a mathematical model which was developed using piecewise linear regression analysis. Another investigation examined the influence of an ordinary water jet on the surface integrity of a particular type of aluminum material. Furthermore, the impact of process parameters on kerf taper ration and surface roughness been discussed in the context of AWJM. A. Ghobeity et al [5] calculated the spatial distribution of erosive efficacy across the mask opening in the Abrasive Water Jet Machining of substrates using an analytical model. Izzet Karakurt et. al. [6] Furthermore, the cutting ability of AWJM on granite has been explored, with a focus on the effects of process parameters and texture properties on the cutting process.

METHODOLOGY

For various jobs, different materials are available and machining them according to the customers' requirements is a complicated task. Selecting the right process parameter

for the required product need some computational basis. The solution can be provided by the VIKOR technique by considering the following settings of process parameters. The following available machine settings are considered for the study.

Table1: Available Settings of Process Parameters

Settings	Pressure (MPa)	Standoff distance (mm)	Abrasive Mass Flow Rate (gm/min)	Traverse Rate (mm/s)	Cutting Orientation (Degree)
1	138	1.5	2.5	1.5	10
2	207	3	2.6	1.6	22.5
3	241	4.5	2.7	1.7	30
4	251	6	2.8	1.8	35
5	271	7.5	2.9	1.9	45

VIKOR Method

A feasible solution that is near to the ideal solution is a compromised solution, and a compromise means an agreement reached by mutual concession.

Table 2: Decision Matrix for VIKOR

Settings	Surface Finishing	Cutting Time	Cost	Geometrical Accuracy	Thickness / Cut
1	4.18	5	132	0.375	16
2	5.30	4.8	120	0.538	18
3	6.1	3.8	110	0.612	20
4	4.38	5.32	130	0.350	17
5	5.23	4.5	116	0.522	19

Formulation of Normalization Matrix can be done using formulas for higher the better and lower the better attributes

Table 3: Normalization Matrix

Settings	Surface Finishing	Cutting Time	Cost	Geometrical Accuracy	Thickness / Cut
1	1	0.76	0.8333	0.9333	0.8
2	0.7886	0.7916	0.9166	0.6505	0.9
3	0.6852	1	1	0.5718	1
4	0.9543	0.7142	0.8461	1	0.85
5	0.7992	0.8444	0.9482	0.6704	0.95

Table 4: Rationalisation

Settings	Surface Finishing	Cutting Time	Cost	Geometrical Accuracy	Thickness / Cut
1	0	0.8397	1	0.1556	1
2	0.6712	0.7289	0.4999	0.8160	0.5

3	1	0	0	1	0
4	0.1450	1	0.9228	0	0.75
5	0.6377	0.5442	0.3102	0.7695	0.25

Table 5: Values of Ei and Fi

Settings	Ei		Fi	
1	0.394930448		0.19	
2	0.605865205	Ei Max	0.1958	
3	0.52		0.28	Fi Max
4	0.369258938	Ei Min	0.1425	Fi Min
5	0.502465625		0.1846	

Calculating the performance index by using following equation and arranging the values in ascending order of it. The compromise solution on the basis of max and minimum values of performance index and expectancy attributes.

Settings	P	Ei	Fi
4	0	0.3692	0.1425
1	0.22710269	0.3949	0.19
5	0.434717337	0.5024	0.1846
2	0.693818182	0.6058	0.1958
3	0.818681319	0.52	0.28

CONCLUDING REMARKS

The overall work includes a study and analysis of existing machining methods. The Process parameters which are considered for the study will have a critical impact on the machining output. The results show optimized machining parameters for toughened glass material for complex shapes and profiles. Setting number 3 will be suitable for cutting toughened glass materials on the abrasive water jet machine

Settings	Pressure (MPa)	Standoff distance (mm)	Mass Flow Rate (gm/min)	Traverse Rate (mm/s)	Cutting Orientation (Degree)
1	138	1.5	2.5	1.5	10
2	207	3	2.6	1.6	22.5
3	241	4.5	2.7	1.7	30
4	251	6	2.8	1.8	35
5	271	7.5	2.9	1.9	45

Since the above setting number 3 ranks first on the basis of VIKOR method it means that this setting will be the best suitable output.

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Applicability of Artificial Intelligence for Logistics in Context with Indian Ecosystem

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ABSTRACT

Implementation of Artificial Intelligence in supply networks may optimize the planning, manufacturing, management, and supply chain operations. Through the analysis of extensive data, forecasting trends, and executing intricate operations in real time, AI may enhance supply chain decision-making and operational efficacy. This study discusses challenges during implementation AI in SCM in Indian sentiments. The study also focuses on machine learning impact to enhance performance of AI.

KEYWORDS : *SCM, AI, Logistics, Predictive logistics.*

INTRODUCTION

Another revolutionary period in human history is upon us today. The global digital revolution is changing many facets of contemporary society, much like the agricultural and industrial revolutions did before it. An increasingly important part of this change is artificial intelligence (AI). AI has emerged from research labs in recent years and has grown so pervasive and ambient in our daily lives that many customers are unaware they use AI-containing products and applications on a daily basis.

All industries stand to gain a great deal from AI, which will be adopted by consumer groups, businesses, and eventually the industrial sector. Big data, algorithmic development, networking, cloud computing, and processor power have all advanced technologically, making AI's performance, affordability, and accessibility better than before. Similar to how relational databases became ingrained in global company operations by offering improved methods for storing, retrieving, and organising data, artificial intelligence is currently doing the same. It will soon be a standard component of all software systems in the future, therefore we won't need to refer to it as artificial intelligence.

What Makes Logistics Important? Why Right Now?

There are several arguments for why the logistics sector should use AI at this moment. This developing technology has never been so widely available and reasonably priced. Narrow types of AI are now widely used in the consumer sector as a result, and the business and industrial sectors will soon follow.

The network-based aspect of the logistics sector makes it an ideal place to apply and scale AI, enhancing the human element of intricate international supply chains. Additionally, businesses that choose not to embrace AI risk becoming obsolete in the long run as rivals quickly adopt and successfully employ AI in their operations.

The Upcoming Operational Model AI has the potential to significantly change the logistics sector's operational paradigm in a world of unpredictability and volatility by assisting in the transition from forecasting and reactive actions to proactive operations using predictive intelligence. Both global, network-level prediction possibilities and process-specific prediction opportunities will be highlighted in this section.

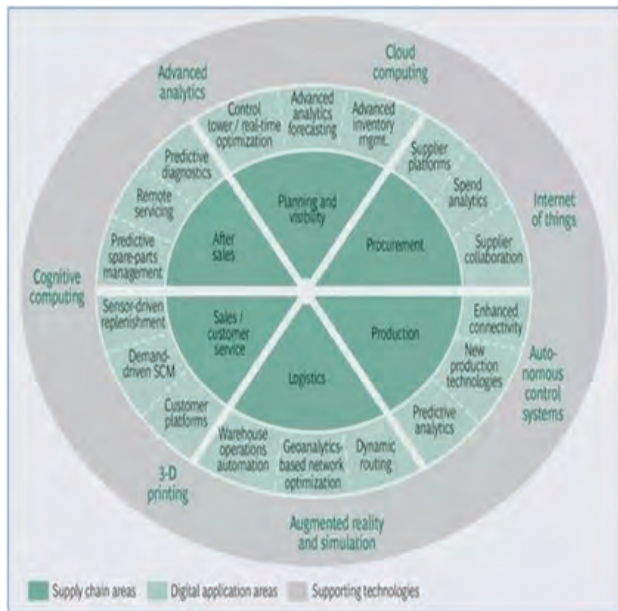


Fig. 1: Areas of Artificial Intelligent in SCM

AI-powered predictive network management may greatly improve logistics operations' performance. Since air freight accounts for just 1% of global trade but 35% of total trade complete shipping is essential. The most of the air-freight channels and networks are designed based on data taken from the market and persons who has expertise in this area and had worked for decades.

To facilitate proactive mitigation, DHL company had generated a AI based tool to forecast air freight delays. The machine learning algorithm can forecast the daily travel time for a particular lane will increase or decrease up to one week ahead of time by examining 58 distinct internal data factors. Additionally, this system may pinpoint the primary causes of shipment delays, such as operational issues like airline on-time performance or temporal ones like departure day. By eliminating arbitrary speculation about when or with which airline their goods should fly, this can assist air freight forwarders in making plans in advance.

A data-driven strategy, predictive logistics makes use of machine learning, sophisticated analytics, and historical data to forecast and improve logistics operations. Businesses can predict possible logistics problems like delays, inventory shortages, or demand spikes by examining real-time data, trends, and patterns. They are able to make proactive changes as a result, increasing productivity and reducing interruptions. By generating

projections, detecting inefficiencies, and stimulating innovation, supply chain predictive analytics assist businesses in streamlining their supply chain operations. Data is enabling supply chain management to achieve goals that were nearly unattainable in the past.

SCENARIO OF INDIAN LOGISTICS

India's economy and progress are based on logistics. Investing in strong supply chains and logistical infrastructure is essential given India's expanding economy. The comprehensive solutions focus on technological, infrastructure, policy, and other components that may address the inefficiencies in India's current logistics systems, which include inefficiencies in inventory management, modal split, truck productivity, and last mile solutions.

Given its degree of penetration into populous regions, road transportation is regarded as one of the most economical and favoured modes of transportation in India, both for people and freight. Consequently, it is essential to the nation's social cohesion and economic growth. With a 4.5% GDP share in 2005–06, road transport has become the largest sector in India's transportation industry. Approximately 60% of all freight traffic in the nation are transported by road. Road transport has several advantages, including cost savings, ease of availability, and flexibility to meet specific demands. Additionally, road transport serves as a feeder service for air, sea, and train traffic.

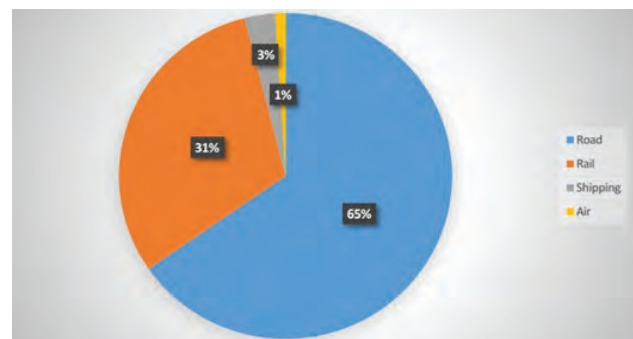


Fig. 2: Share of Freight logistic in India in 2023

Digital, Operational, and Technological Solutions The foundation of an effective supply chain is digitization, and technology is its primary enabler. India is now ranked 146th out of 190 nations in the World Bank's "Doing Business" initiative's "Trading across Borders" component.

"Doing Business" evaluates how a shipment of products is exported or imported and assigns a score to a nation

based on the amount of time and money spent on domestic transportation, border compliance, and documentation compliance. Ineffective urban distribution, high inventory costs, and low productivity methods may all be resolved using digitization when paired with the right technology, such as artificial intelligence. This is the platform that combines the supply chain, load consolidation and dispatch scheduling.

CHALLENGES OF AI IN SUPPLY CHAIN

- Using AI to supply chain planning and management won't happen fast. Although network requires ongoing work. Running AI systems is a continual process that requires robust platform such cloud based virtual machines, even if it doesn't require as much processing power as training to AI systems.
- However, because to these cloud-based solutions, AI technology is becoming more accessible and affordable. Additionally, some cloud technology providers offer managed platforms that facilitate the machine learning models, automate their development, and maintain AI tool.

there is a lot of promise for cost savings and process simplification, the technology may occasionally be costly and challenging to implement. When incorporating intelligence into their supply chain operations, businesses usually run into several issues.

- The cost of instruction as with new technology, putting Artificial Intelligence tool into practice settings requires training to the people who will be using often scary technologies.
- It usually costs money to schedule some downtime in order to train staff and overcome their aversion to change. Partners across the supply chain should collaborate with their AI suppliers or integrators to create training programs that are both beneficial and reasonably priced before this downtime occurs. However, it should be noted that any training strategy will probably have a cost. The costs of start-up and operation. AI implementation costs generally extend beyond the integration of the software used by these systems. There are prebuilt models that can be altered to use a range of supply chain cases, so machine learning coding isn't always required.
- Companies should train models on their data to optimise benefits. To collect data then combining

and processing large amounts of quality data can be challenging.

- The compute process of training the ML model with this data often requires servers with graphics processing units, which can monopolise on resources and raise service costs. Managing and running AI systems at scale in a global logistics.
- Intricate systems. The systems that streams real-time data, GPU-powered servers that train machine learning models initially and over time, run those models in production, and apps that respond to patterns found or suggestions made are just a few of the many moving components that make up AI systems. These components must be integrated by organisations throughout the numerous nodes of an international supply chain. Additionally, they have to continually examine these systems, adjust their functionality, and find and address any issues.

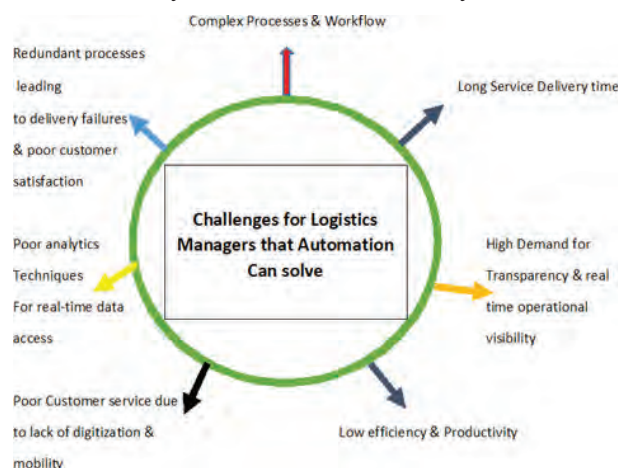


Fig. 3: Challenges of AI in Logistics and SCM

CONCLUSION

The current state of technology, business, and society has never been more conducive to the broad usage and adoption of artificial intelligence (AI), despite previous waves of hype and disillusionment. Artificial Intelligence is already here to stay in the consumer sphere. Leading business sectors that are far along in their AI journeys include technology, finance, and, to a lesser extent, mobility. Logistics and other industrial company sectors are currently starting theirs in earnest. Using insights from the consumer, business, retail, mobility, and manufacturing sectors offers important insight into how artificial intelligence (AI) might be used effectively in

logistics. The laborious duties that characterise many facets of contemporary working life will be lessened by enterprise AI.

Logistics networks will transition to a proactive and predictive paradigm as AI processes and exposes large data from operational, public, and private sources. Logistics operators will be able to observe, comprehend, and engage with the world in new and more effective ways thanks to computer vision and language-focused AI. A new class of intelligent logistical assets that enhance human capabilities will emerge as a result of these same AI technologies. Additionally, logistics companies can use AI to deliver goods before customers have even placed their orders and improve customer experiences through conversational engagement.

AI is not without its difficulties, though. The system's decision-making processes may become entangled with the prejudice and intentions of each AI developer, posing difficult ethical dilemmas for AI models. In this case, norms and laws must be created by industry, society, and governmental agencies to guarantee AI's continuous advancement for the sack of humanity.

We think there is a lot of promise for AI in logistics. AI will become more prevalent and integrated into daily operations as supply chain executives continue their digital transformation journey, speeding up the transition to a proactive, predictive, automated, and personalised logistics future. In the end, AI will prioritise human intuition, communication, and connection, enabling humans to participate in more fulfilling jobs.

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Recent Advancements in the Machining and Surface Integrity of Nickel-Based Alloys: A Review

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ABSTRACT

Nickel-based superalloys are crucial in high-performance applications like aerospace, energy, and automotive due to their high strength, corrosion resistance, and creep resistance. However, these properties pose challenges in machining, necessitating ongoing research to improve efficiency and precision. This review explores recent advancements in nickel-based alloy machining, focusing on strategies to enhance machinability and surface integrity. Key challenges include high strength and hardness leading to elevated cutting forces and tool wear, low thermal conductivity resulting in high cutting temperatures, and work hardening tendencies complicating the machining process. Innovative machining techniques include cryogenic cooling, vibration-assisted machining, and advanced tooling solutions. Non-conventional methods like Electrical Discharge Machining and Electrochemical Machining are also analyzed for their effectiveness. The review also discusses the impact of additive manufacturing and post-processing techniques on nickel-based component fabrication. Surface integrity is crucial for performance and longevity, and methods for enhancing it through optimized machining parameters and advanced cooling strategies are highlighted.

KEYWORDS : EDM, NTM, Nickel based alloy.

INTRODUCTION

Nickel-based superalloys are high-performance materials prized for their exceptional properties at elevated temperatures, including high strength, corrosion resistance, and creep resistance [1], [2]. These characteristics make them indispensable in demanding applications within the aerospace, energy, and automotive industries [1], [3]. However, their very properties that render them so valuable also present significant challenges in machining, making the efficient and precise processing of these alloys a persistent area of research and development [1], [4]. This review examines recent advancements in the machining of nickel-based alloys, focusing on the strategies employed to enhance machinability and improve surface integrity. Table 1 shows the characteristics and applications of Nickel based Alloy in industries.

CHALLENGES IN MACHINING NICKEL-BASED ALLOYS

The inherent difficulties in machining nickel-based alloys

stem from a combination of material characteristics:

- **High Strength and Hardness:** The exceptional strength and hardness of these alloys lead to high cutting forces, increased tool wear, and potential
- for tool breakage [1], [5]. This necessitates the use of specialized tooling and cutting parameters.
- **Low Thermal Conductivity:** The poor thermal conductivity of nickel-based alloys results in high cutting temperatures, which can lead to tool wear, workpiece damage (such as the formation of white layers), and adverse changes in the microstructure [4], [6]. Effective cooling strategies are crucial to mitigate these effects.
- **Work Hardening:** The tendency of nickel-based alloys to work harden during machining further exacerbates tool wear and increases cutting forces [1], [7]. This necessitates careful consideration of cutting parameters and potentially the use of advanced cutting fluids.

Complex Microstructures: The complex microstructures of these alloys, often involving precipitates and various phases, can influence the cutting process and contribute to tool wear [8], [9]. Understanding the microstructure and its effect on machinability is crucial for optimizing the process.

ADVANCEMENTS IN MACHINING TECHNIQUES

Researchers and engineers have explored various strategies to overcome the challenges posed by machining nickel-based alloys. These advancements can be broadly categorized into:

Conventional Machining with Enhanced Techniques

While conventional machining methods like turning, milling, and drilling remain relevant, significant improvements have been achieved through the integration of advanced techniques:

High-Performance Cooling: Cryogenic machining, which employs extremely low temperatures, has shown promise in reducing cutting temperatures and improving tool life [10], [11]. Minimum Quantity Lubrication (MQL) techniques, involving the application of minimal amounts of cutting fluid, offer an environmentally friendly approach to reducing cutting temperatures and enhancing lubrication [10], [5]. The combination of cryogenic cooling and MQL further enhances the benefits of both approaches [10], [11]. High-pressure lubricoolant supply also plays a role in improving cooling and lubrication [10]. The use of hybrid nanofluids in MQL systems has been explored to further enhance the cooling and lubrication capabilities [6], [12]. Studies have shown that vegetable oil-based nano lubricants can be effective alternatives to traditional mineral-oil based cutting fluids [13], [14], offering a more sustainable approach to machining. A comparative assessment of different bio lubricants for aerospace alloy grinding has demonstrated their potential as a replacement for traditional mineral cutting fluids [15].

- **Vibration-Assisted Machining:** Low-frequency and high-frequency vibration-assisted machining

techniques have demonstrated potential in improving surface finish and reducing cutting forces [10], [16]. Ultrasonic vibration, in particular, has shown promising results in combination with MQL [16].

Non-Conventional Machining Techniques

Non-conventional machining techniques offer alternative approaches to process nickel-based alloys:

Electrical Discharge Machining (EDM): EDM, including Wire EDM (WEDM), is a widely used non-conventional method for machining complex shapes and hard-to-machine materials [20], [21]. Studies have explored the optimization of EDM parameters to achieve desired surface roughness and material removal rates [20], [22]. The addition of multi-walled carbon nanotubes (MWCNTs) to the dielectric fluid in WEDM has shown improvements in material removal rate, recast layer thickness, and surface roughness [22]. Further research has investigated the use of additive manufactured tool electrodes in EDM to enhance machinability [23]. The use of POCO graphite electrodes in EDM of Hastelloy C-22 has been investigated, showing that graphite with smaller grain size provides lower surface roughness [24]. Machining B1914 nickel-based superalloy using WEDM has been extensively studied, optimizing parameters to improve cutting speed and surface quality [25].

- **Electrochemical Machining (ECM):** ECM is another non-conventional technique that utilizes electrochemical processes to remove material [26]. Research has focused on optimizing ECM parameters to minimize nickel emissions in the sludge while maximizing material removal rate [26].
- **Laser-Assisted Machining:** Laser-assisted machining, involving the use of lasers to pre-treat the workpiece or assist in the cutting process, offers potential for improved surface quality and reduced cutting forces [10], [27]. Laser-based manufacturing and surface modification techniques are being explored for high entropy alloys (HEAs), potential alternatives to nickel superalloys [27].

Table 1: Non-Conventional Machining Techniques for Nickel-Based Alloys

Machining Technique	Principle	Advantages	Limitations	Common Applications
Electrical Discharge Machining (EDM)	Uses electrical sparks to erode material from the workpiece.	Suitable for complex shapes, minimal mechanical stress, works on hard alloys.	Slow material removal rate (MRR), high tool wear, high energy consumption.	Turbine blades, aerospace components, medical implants.

Electrochemical Machining (ECM)	Uses controlled anodic dissolution of material in an electrolytic medium.	No tool wear, high surface finish, ideal for difficult-to-machine alloys.	High initial cost, requires proper electrolyte disposal.	Aerospace parts, fuel injectors, micro-machining
Abrasive Water Jet Machining (AWJM)	Uses high-pressure water and abrasive particles to erode material	No heat-affected zone, suitable for intricate shapes, minimal burr formation.	Limited material thickness, high operating costs.	Cutting aerospace components, turbine parts.
Laser Beam Machining (LBM)	Uses a high-energy laser beam to melt and vaporize material.	High precision, contactless process, minimal tool wear.	Heat-affected zones, potential microcracks, expensive setup.	Micro-drilling, engraving, medical devices.
Electron Beam Machining (EBM)	Uses a focused electron beam to heat and vaporize material in a vacuum.	High precision, minimal mechanical stress, ideal for thin materials.	Requires vacuum environment, limited to conductive materials.	Aerospace, micro-electronics, precision drilling.
Plasma Arc Machining (PAM)	Uses a high-temperature plasma arc to cut through conductive materials.	High cutting speed, suitable for thick sections, can cut hard alloys.	Produces heat-affected zones, requires fume extraction.	Aerospace and automotive industries, structural components.
Ultrasonic Machining (USM)	Uses high-frequency vibrations with an abrasive slurry to remove material.	Minimal heat generation, suitable for brittle and hard materials.	Low material removal rate, limited to small-scale machining.	Precision machining of turbine blades and medical components.

ADDITIVE MANUFACTURING AND POST-PROCESSING

Additive manufacturing (AM) techniques, such as Selective Laser Melting (SLM), are increasingly used to produce near-net shape components from nickel-based alloys [3], [8]. While AM reduces material waste and lead times, post-processing machining is often necessary to achieve the required dimensional accuracy and surface finish [8], [28]. The influence of SLM process parameters on the surface integrity of difficult-to-cut alloys has been comprehensively reviewed, addressing parameters like composition, grain size, and defects [3]. Studies have investigated the optimization of SLM parameters to achieve higher surface quality and microhardness [29]. Post-processing heat treatments, such as solution and aging treatments, are also used to optimize the microstructure and mechanical properties of additively manufactured nickel-based alloys [30]

Surface Integrity and its Enhancement

Surface integrity is a critical aspect of machined components, influencing their fatigue life, corrosion resistance, and overall performance [9]. The high cutting temperatures and forces involved in machining nickel-based alloys can lead to surface damage, including

the formation of white layers, residual stresses, and microcracks [4], [9]. Several techniques are used to improve surface integrity:

- **Optimized Machining Parameters:** Careful selection of cutting parameters, such as cutting speed, feed rate, and depth of cut, is crucial in minimizing surface damage [20], [5].
- **Advanced Cooling and Lubrication:** Effective cooling and lubrication strategies are essential in reducing cutting temperatures and minimizing surface damage [5], [6]. The use of MQL, cryogenic cooling, and nanofluids significantly improves surface finish [5], [6].

RESEARCH GAPS AND FUTURE DIRECTIONS

Despite significant advancements, several research gaps remain:

- **Further Development of Sustainable Coolants:** While MQL and nanofluids show promise, further research is needed to develop more sustainable and efficient cooling and lubrication strategies [12], [14]. The exploration of bio lubricants and their optimization for specific machining operations is crucial [15], [24].

- Advanced Process Modelling and Simulation: More accurate and comprehensive process models are needed to predict machining performance and optimize cutting parameters [25], [9]. The incorporation of dynamic recrystallization effects in simulations is important for accurately predicting residual stresses [9].
- Understanding Microstructure-Property Relationships: A deeper understanding of the relationship between the microstructure of nickel-based alloys and their machinability is crucial for designing optimized machining processes [8], [9].

CONCLUSION

Significant progress has been made in enhancing the machinability and surface integrity of nickel-based alloys. The integration of advanced cooling techniques, vibration-assisted machining, advanced tooling, and non-conventional machining methods has led to improved machining performance and surface quality. However, continued research is necessary to address the remaining challenges, particularly in developing more sustainable machining processes, improving process modelling capabilities, and leveraging the potential of AI and machine learning. Focusing on the interplay between material microstructure, machining parameters, and surface integrity will be crucial in achieving further advancements in this field. The development of more environmentally friendly cutting fluids and the integration of life cycle assessment principles into machining processes are essential for promoting sustainable manufacturing practices [14], [18]. The ongoing research in this area promises to further enhance the efficiency and sustainability of machining nickel-based alloys for diverse high-performance applications.

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A Review on Stress Analysis of Machine Tool Holders

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ABSTRACT

The performance and durability of a machine tool holder significantly influence machining accuracy and tool life. This study presents a comparative stress analysis of machine tool holders with varying locating positions and materials using Finite Element Analysis (FEA). The objective is to examine how different locating positions and material choices affect stress distribution and structural integrity under typical operational loads. The analysis includes commonly used materials, such as steel, titanium, and advanced composites, to evaluate their behaviour under the same conditions. Various locating positions are also assessed to identify stress concentration points and deformation patterns that may impact the tool holder's performance. By conducting detailed FEA simulations, this research aims to determine the optimal configuration of locating positions and material selection that minimizes stress and enhances the tool holder's durability. The results offer valuable insights for manufacturers and designers, leading to improved tool holder designs that ensure better stability, increased tool life, and higher machining precision. These findings are essential for advancing machine tool technology and improving overall manufacturing efficiency.

KEYWORDS : Machine tool holder, Stress analysis, Stress distribution, Machining accuracy, Finite element analysis.

INTRODUCTION

Precision and stability are fundamental requirements in modern manufacturing, where the quality of machining processes determines the success of final products. Among the key components that directly influence machining accuracy is the machine tool holder, a critical part responsible for securely holding the cutting tool during operations. The performance of the tool holder not only impacts the precision of machining but also affects the lifespan of both the tool and the holder itself. However, during machining operations, tool holders are subjected to complex and varying loads, leading to stress concentrations that can cause deformation, wear, and eventual failure if not properly addressed. The durability and efficiency of a machine tool holder are largely influenced by factors such as the locating position and material composition. Traditional materials like steel and titanium have been widely used in tool holders due to their strength and resilience under stress. However, with the advancements in materials science, composite materials have emerged as potential alternatives, offering the possibility of reducing

weight while maintaining or even enhancing performance. Selecting the optimal material and locating position is crucial to minimizing stress concentrations and improving the tool holder's overall performance.

This study aims to conduct a comparative stress analysis of machine tool holders with different locating positions and material selections using Finite Element Analysis (FEA). FEA is a powerful computational tool that allows for detailed simulation of stress distribution and deformation behavior under various loading conditions. By applying FEA to different tool holder configurations, this research seeks to identify the stress distribution patterns that occur due to variations in locating positions and material properties. The primary objective of this study is to analyze how different locating positions impact the stress distribution within the tool holder. Various positions will be considered, each representing common setups used in industry. In addition, the study will evaluate the effects of different material compositions, including traditional metals like steel and titanium, as well as advanced composites. By comparing these variables, the research

will identify the optimal configurations that minimize stress concentrations and enhance the tool holder's structural integrity.

The findings from this study will provide valuable insights for the design and optimization of machine tool holders. Manufacturers and designers can use these insights to develop more robust and efficient tool holders, ultimately leading to improved machining accuracy, extended tool life, and enhanced manufacturing efficiency. Additionally, the study's results may guide future research in the field of material science and structural optimization for machining tools, paving the way for further advancements in manufacturing technology. This project work addresses a critical gap in the understanding of stress behavior in tool holders, offering practical solutions to enhance the performance of machining systems.

to identify the most effective configurations that minimize stress concentrations and enhance the longevity of tool holders. Hence, to overcome the challenge's, this work will focus on "Comparative stress analysis of machine tool holder with different locating positions and material using FEA"

OBJECTIVES

1. To analyze the stress distribution in machine tool holders with varying locating positions using Finite Element Analysis (FEA).
2. To evaluate the impact of different material selections on the structural integrity of machine tool holders.
3. To compare the deformation and stress concentration patterns in tool holders under typical operational loads.

METHODOLOGY

Literature Review

Conduct a comprehensive review of existing research and case studies on machine tool holders, focusing on stress analysis, material properties, and locating positions. Identify gaps in current knowledge regarding the impact of different materials and locating positions on tool holder performance.

Material Selection

Identify and select materials for the tool holders, including traditional metals (steel, titanium) and advanced composites. Obtain material properties such as Young's

modulus, yield strength, and thermal conductivity from reliable sources or experimental testing.

Finite Element Analysis (FEA) Setup

Create detailed 3D models of the tool holders using CAD software. Import these models into an FEA software tool and set up the simulations, including boundary conditions, loads, and constraints representative of real-world machining scenarios. Define different locating positions and material properties for the simulations.

Simulation and Analysis

Perform FEA simulations to analyze stress distribution, deformation, and potential failure points under various locating positions and material configurations. Record and compare results for different scenarios to identify stress concentrations and structural weaknesses.

Comparison

Analyze the simulation results to evaluate the performance of different locating positions and materials. Identify optimal configurations that minimize stress concentrations and improve the tool holder's durability and performance.

Recommendations

Based on the analysis, provide design recommendations for improving machine tool holder configurations. Suggest optimal locating positions and material choices to enhance performance and extend tool life.

Need

The performance and longevity of machine tool holders are critical for ensuring precision and stability in machining operations. Tool holders, subjected to complex and variable stresses during use, can experience deformation, wear, and failure, affecting machining accuracy and manufacturing efficiency. With advancements in materials and manufacturing technologies, optimizing tool holder designs is essential to meet modern demands. Identifying the optimal combinations of materials and locating positions can enhance performance, extend tool life, and reduce maintenance costs. Current research lacks comprehensive exploration into how different locating positions and materials influence tool holder stress distribution, presenting a significant gap in knowledge. This project aims to address this gap by employing Finite Element Analysis (FEA) to analyze various configurations, providing valuable insights for optimizing tool holder designs. By improving tool holder technology, this project

will contribute to better machining accuracy, increased productivity, and cost-effective manufacturing processes, meeting the growing demands of complex and high-precision machining applications.

Scope

This project will involve a comprehensive analysis of machine tool holders to enhance their performance and durability. The work will begin with a literature review to establish the foundation of current knowledge regarding stress analysis, material properties, and locating positions for tool holders. Representative tool holder designs will be selected and modeled using 3D CAD software, incorporating various locating positions and materials. The study will then focus on selecting materials, gathering the necessary material properties for Finite Element Analysis (FEA).

LITERATURE SURVEY

This literature survey reviews recent advancements and methodologies in the application of Finite Element Analysis (FEA) to machine tool design and performance evaluation. The focus is on analyzing fatigue life, thermal and mechanical behavior, and structural optimization of machine tools. The application of Finite Element Analysis (FEA) has revolutionized the design and optimization of machining components such as tool holders, spindles, and cutting tools, offering insights into their structural, thermal, and dynamic behaviors. A detailed examination of recent studies provides a comprehensive understanding of the advancements in this field.

The key literature survey is mention below-

Afolabi et al. (2019) explored the design and fatigue life prediction of machine shafts using FEA, emphasizing the importance of safe and economical design practices. Their work provides a foundational approach to predicting fatigue failures in machine components, which is critical for improving reliability and performance.

Akdeniz and Arslan (2024) introduced a new tool holder design aimed at reducing vibrations during turning operations. Their experimental and FEM analyses demonstrated that the modified design significantly improved machining stability and surface quality, providing a practical solution to the persistent issue of vibration in machining processes. Al-Bahkali and Abbas (2018) conducted a failure analysis of vise jaw holders in hacksaw machines. Using FEM, they identified zones with

high-stress concentrations that led to premature fractures. Their study recommended material changes and design improvements to enhance the durability and reliability of these components.

Armendia et al. (2019) evaluated the digital twin concept for machine tools in an industrial environment, demonstrating the integration of virtual models with real-world operations. This approach enhances understanding and management of machining processes, allowing for more accurate simulations and predictions.

Arslan (2014) explored the thermal and structural behaviors of shrink-fit tool holders through coupled thermal-structural FEA. His study revealed how thermal expansion and contraction affect the structural integrity and clamping performance of tool holders. By simulating these effects, Arslan provided recommendations for selecting materials and designs that maintain thermal stability under extreme operating conditions.

Cakir and Yahya (2005) analyzed cutting tools subjected to extreme conditions in hard turning operations. Their FEM simulations revealed stress distribution patterns that precede tool fractures, enabling the development of more robust cutting tools capable of withstanding high loads and temperatures.

Chan et al. (2023) applied FEA and topology optimization to improve the structural design of gantry-type high-precision machine tools. They achieved lightweight yet rigid structures, which are crucial for maintaining precision while reducing energy consumption and material costs. Their research highlights the potential of combining structural optimization techniques with FEM to meet the evolving demands of the manufacturing industry.

Chan et al. (2023) conducted a study on the structural optimization of a gantry-type high-precision machine tool using FEA. Their research highlights the importance of optimizing machine tool structures to achieve high precision and performance, thereby addressing issues of rigidity and accuracy. Chen and Lin (2014) analyzed the clamping force distribution in high-speed tool holders using contact element analysis. They demonstrated that an optimized clamping force distribution not only improves tool stability but also minimizes deformation during high-speed machining. Their findings offer practical guidelines for tool holder design, particularly for applications requiring high rotational speeds. Chinnuraj et al. (2020) analyzed the static and dynamic behavior of a CNC lathe

bed reinforced with steel-epoxy granite using FEA. Their study illustrates how material reinforcement affects the mechanical behavior of machine components, contributing to better vibration control and structural stability.

Ertürk et al. (2006) combined analytical modeling with FEM to study spindle-tool dynamics using the Timoshenko beam model and receptance coupling. Their work provided a detailed understanding of the tool point frequency response function (FRF), offering strategies to suppress unwanted vibrations and enhance machining performance.

Huo et al. (2004) developed a novel FEA model for the integral analysis of machine tools and machining processes. This model aims to enhance the understanding of the interaction between machine components and operational conditions, facilitating improved design and performance analysis.

Kumaraswamy et al. (2021) focused on the thermal analysis of hybrid metal matrix composites used in automotive engine valves. Their work highlights the application of FEA in predicting thermal behavior, which is essential for managing thermal stresses in high-temperature environments.

Liu and Lin (2019) performed a thermal-mechanical coupling analysis on CNC machine tool feed mechanisms, addressing the impact of thermal effects on mechanical performance. Their study provides insights into how temperature variations can influence tool behavior and accuracy.

Mian et al. (2011, 2013) conducted investigations into thermal error prediction and distortion estimation of machine tools using FEA. Their research underscores the significance of accurate thermal modeling for mitigating errors due to environmental temperature changes. Mohring et al. (2016) emphasized the integration of simulation tools in the design of intelligent machine tool components. By coupling FEM with mechatronic systems, they demonstrated the potential for developing adaptive and efficient machining systems that respond dynamically to operational conditions. Revanasiddesh et al. (2020) extracted modal parameters of CNC lathe beds using both FEA and experimental methods. Their work offers a comprehensive approach to understanding dynamic behavior and improving modal analysis techniques. Sheng et al. (2004) employed adaptive FEM to simulate variable blank holder forces in the conical cup drawing process.

Their methodology allowed real-time adjustments to the blank holder force, optimizing the forming process and minimizing defects.

Soori and Arezoo (2023) reviewed modifications in CNC machine tool operations and structures using FEA, providing a broad overview of advancements in enhancing machine tool performance through structural and operational changes. Tripathi et al. (2022) extended the study of vibration analysis to single-point cutting tool holders. Their research focused on minimizing chatter, a critical problem that affects machining quality and tool life. By using FEA, they identified the critical vibration modes and proposed structural modifications, which significantly enhanced the tool holder's dynamic stability and machining performance.

Verma and Pradhan (2020) investigated CNC turning processes for various tool inserts and workpiece materials, combining experimental and numerical methods to optimize cutting conditions and improve machining outcomes.

Wang et al. (2012) investigated the dynamic behavior of tool holder-spindle assemblies using FEA. By performing modal analysis, they identified the natural frequencies and mode shapes, which play a critical role in the stability and accuracy of CNC milling machines. Their work emphasized how resonance phenomena and vibration modes influence machining precision and surface quality. This study serves as a foundation for optimizing tool holder designs to reduce vibration and improve machine tool performance.

Yıldız et al. (2020) simulated drilling operations and analyzed drill stresses using FEA, contributing to a better understanding of stress distribution during drilling and helping to optimize drill design and performance.

This survey highlights the diverse applications of FEA in improving machine tool design and performance, encompassing fatigue life prediction, thermal and mechanical behavior analysis, and structural optimization. Each study contributes to a broader understanding of how FEA can be leveraged to enhance the reliability and efficiency of machining processes.

INFERENCES FROM LITERATURE

This survey uncovers the transformative impact of Finite Element Analysis (FEA) on machine tool design and performance. Recent studies highlight how FEA is

revolutionizing the field by offering deeper insights into component behavior and process optimization. Afolabi et al. (2019) reveal how FEA predicts fatigue life, paving the way for more reliable and long-lasting machine components. Armendia et al. (2019) show that digital twin technology, when combined with FEA, elevates predictive maintenance and operational efficiency, making virtual simulations an essential tool for modern machining. Chan et al. (2023) demonstrates that structural optimization via FEA enhances the precision and stability of high-precision machine tools. Similarly, Chinnuraj et al. (2020) prove that material innovations, such as steel-epoxy granite composites, significantly improve the performance and stability of CNC lathe beds. Huo et al. (2004) presents an integrated FEA model that offers a comprehensive view of machine tools and their processes, advancing design and performance analysis. Kumaraswamy et al. (2021) and Liu & Lin (2019) underscore the importance of integrating thermal and mechanical analysis to manage thermal stresses and maintain precision.

Mian et al. (2011, 2013) highlights the critical role of accurate thermal error prediction in maintaining machining accuracy. Revanasiddesh et al. (2020) show how combining FEA with experimental methods refines our understanding of dynamic behavior and enhances machine stability. Soori and Arezoo (2023) explore how FEA-driven modifications to CNC machines can significantly boost performance, while Verma and Pradhan (2020) demonstrate how blending experimental and numerical approaches optimizes CNC turning processes. Yang et al. (2020) emphasizes the necessity of vibration control, and Yıldız et al. (2020) offer insights into stress analysis for improving drill design.

Problem Statement

In modern machining operations, machine tool holders play a critical role in ensuring the precision, stability, and efficiency of the process. However, tool holders are subjected to complex and variable stresses during operation, leading to potential issues such as deformation, wear, and failure. These issues can compromise machining accuracy, reduce tool life, and increase downtime, ultimately affecting the overall productivity and cost-effectiveness of manufacturing processes.

One of the key challenges in optimizing the performance of machine tool holders is understanding how different locating positions and material selections influence stress distribution within the holder. Currently, there is a lack

of comprehensive analysis that compares the effects of different locating positions and material choices on the stress behavior of tool holders. Without this knowledge, manufacturers and designers may struggle

Implementation of Finite Element Analysis

Mesh Discretization Methodology

The computational domain was discretized utilizing high-order tetrahedral elements (ANSYS SOLID185) to facilitate comprehensive numerical simulation. The selected element topology, characterized by quadratic interpolation and ten nodal points, enables enhanced representation of complex geometric morphologies and stress distribution characteristics.

Element Specification:

- Type: SOLID185 (10-node tetrahedral element)
- Interpolation: Quadratic displacement
- Nodal Configuration: 4 corner nodes, 6 mid-side nodes

Meshing Strategy: A higher-order tetrahedral mesh was implemented to capture intricate geometric details and ensure accurate stress propagation analysis. The mesh discretization approach facilitates superior numerical convergence and provides robust computational representation of the structural mechanics under investigation. The mesh generation strategy emphasized adaptive refinement, allowing localized mesh density modifications to optimize computational efficiency and numerical precision in critical regions of geometric interest.

Summary

- The project focuses on optimizing the performance of machine tool holders by investigating their stress behavior under different configurations.
- Machine tool holders are essential for ensuring precision and efficiency in machining operations but face challenges such as deformation, wear, and failure due to complex stresses.
- The study addresses these challenges by analyzing how different locating positions and material choices affect stress distribution and deformation using Finite Element Analysis (FEA).
- The methodology involves creating FEA models with varying configurations, applying material properties

and boundary conditions, and implementing meshing techniques to ensure accurate simulations.

- A thorough literature survey highlights existing gaps and emphasizes the need for systematic analysis of these factors.

The findings will provide valuable insights into stress behavior, guiding the design of more durable and efficient tool holders.

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Examining the PCM-based Battery Thermal Management System for Lithium-Ion Batteries

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ABSTRACT

Electric vehicles are developing fast and are easily popular because of their no emission. However some barriers are there in the development of electric vehicle like battery performance, cost, life time and its safety. Therefore management of battery is very important in electric vehicle. To be more precise battery thermal management is required to be considered as important aspect. The purpose of battery thermal management system is to maintain battery safety and efficient use as well as ensure the battery temperature within optimal range. This paper delves into the use of Paraffin Wax as a Phase Change Material (PCM) within BTMS to address overheating and optimize performance. Paraffin wax, renowned for its advantageous thermal properties, is explored for its ability to regulate battery temperatures by undergoing liquid-solid phase transitions. The cells are placed in a 3 x 5 rectangular configuration in the metallic casing which is having ability to hold PCM. This experimental setup models the heat generation of a lithium-ion battery by utilizing a resistor that produces an equivalent amount of heat energy per unit volume as a real lithium-ion cell would. The battery module kept in natural convection rapidly heated up to 41.43°C in 300s. Further if the same battery pack when kept in phase change material for the same period of time shows the temperature of 32.56°C.

INTRODUCTION

As a key component in the transition to cleaner energy, lithium-ion batteries have rapidly replaced fossil fuel-based power sources in recent years, aiming to significantly reduce carbon emissions and promote a more environmentally sustainable ecosystem. The automobiles using internal combustion engines increases the carbon pollution causing global warming and hence vibrates the ecosystem[7]. We can say batteries are the brains of electric vehicles, but lot of heat and temperature get generated during both charging and discharging. Decomposition of battery material and increase in temperature of the battery both are responsible in thermal runaway process [8]. So

that an explosion of batteries may happen due to this high temperature which leads to battery into thermal runaway [9]. The versatile battery materials and manufacturing techniques helps to improve the energy density of batteries in last couple of years. The automobile industries are expecting lithium-ion batteries as a promising energy storage devices which should have high specific power and high energy density. But there is one major problem with these batteries that is these are very sensitive to temperature [10, 11].

Thus, to decrease the increased temperature of the battery pack and to distribute the temperatures in the cell equally which can extend the efficiency, life and safety of batteries

the BTMS was developed. LiBs temperature can be maintained within the optimal range from 15°C to 35°C by using BTMS, while the temperature non-uniformity of batteries in a module is below 5°C [12,13]. There are two main categories of BTMS namely active and passive thermal management systems. In an active battery thermal management system, a coolant, generally air/gas or water-based mixture with an additive like glycol is circulates through passage within the battery pack. It can absorb heat generated during battery operation, with a great heat absorption capacities [14]. So in this first category external power source is required to operate pumps or fans and hence it is called as active cooling system. The heat from the battery is transferred to the coolant which is then flows to an external heat exchanger, where it releases the heat into the surrounding environment. This method supports to maintain the battery temperature within its optimal range, which is around 20°C and 25°C, ensuring extension of battery's lifespan and efficient operation [15].

PCMs serve as thermal energy storage units in passive BTMs that combine them with hydrogels, heat pipes, and PCMs. Their latent heat ranges from 150 to 250 Jg⁻¹. Comparing this integrated PCM-based BTMS to active BTMS, it has shown an impressive 19.4% reduction in maximum battery temperatures [16]. The PCM absorbs heat as the battery heats up and changes from a solid to a liquid, keeping the temperature steady without the need for electricity. This attribute is what gives the BTMS an increased degree of net efficiency [17]. But as per the research, PCM-based BTMs rarely appear in EVs [18].

Currently, thermal management techniques have developed from traditional air-based cooling [19] and indirect cooling using liquids [20,22] to cooling of phase change material (PCM) [23], heat pipe [24,25], and immersion cooling [26].

The initial concept of the phase transition material-based BTMS came from Al-Hallaj and Selman [27]. The heat management system for lithium ion batteries was examined in their study's performance utilizing both PCM and air. The results demonstrated that both the ambient temperature and the battery's discharge rate considerably affect the operation of the air-cooling management system, with moderate discharge rates and high ambient temperatures rendering it impossible to maintain a safe battery temperature [28]. The effect of using fins on improving battery TMS performance was experimentally investigated by Wang et al. They employed paraffin, which has a melting point of 44°C, in their procedure. An 8°C drop in average battery temperature was observed [29].

High latent heat storage PCMs are an extremely efficient passive cooling technique for lithium-ion batteries. Although battery thermal management systems (TMSs) have been subjected to extensive numerical testing in the past, the numerical analysis of battery TMSs has undergone numerous simplifications in order to achieve positive outcomes. It is impossible to do a numerical study of the impacts of a changing ambient temperature in real time. In order to analyze batteries and investigate cell temperatures in both natural convection and when placed in PCM at varied discharge rates, we have developed an experimental model. Using paraffin wax as a prime phase transition material, this article focuses on developing a state-of-the-art Battery Thermal Management System (BTMS) in response to the growing demand for safer and more effective automobile batteries. Thermal control and preventing overheating have become a key concern due to the growing usage of high-energy-density batteries in automobiles.

LITERATURE REVIEW

Battery thermal management via liquid or air cooling was the main focus of the majority of the study.

For lithium ion batteries in electric vehicles to regulate operating temperature and temperature variations, a thermal management system is necessary. The study of battery thermal management systems (BTMS) frequently makes use of phase change material (PCM). To transport the heat produced by battery cells, pure PCM is insufficient because to its limited thermal conductivity. By mixing paraffin with copper foam, which is essentially a composite phase change material (CPCM), the thermal conductivity of PCM was improved in order to address this issue [1]. According to research by Reabra Youssef et al., the periodic load profile verifies that the maximum temperature for the cooling strategies of no-cooling, PCM cooling, and PCM with jute is 39.22 °C, 38.22 °C, and 35.09 °C, respectively. Future research will concentrate on the difficult pre-degradation of jute fiber [2]. Zhang et al. described Paraffin & EG as a PCM that can enhance the heat dissipation source to effectively control the temperature rise up to peak temperature up to 42°C. Additionally, the thermal conductivity of CPCM reaches a maximum value of 3.084 W • m⁻¹ • K⁻¹ at 40° C, which is nearly 12 times higher than that of PA [3]. Chongmao Mo et al. showed that by adding 5.5 weight percent of EG, the CPCM exhibits an increased thermal conductivity from 0.23 to 2.2 W m⁻¹ K⁻¹, and the addition of epoxy resin

with CPCM can help prevent PCM leakage during high temperature conditions [4]. In their assessment of lithium-ion battery performance characteristics, Rathode et al. talk about the technology of phase change materials in battery temperature management systems [5]. LiFePO₄ batteries are now the best options for electric vehicles due to their low temperature, safety, and long service life. Using PCM and heat pipes, as well as air or liquid cooling strategies, are some of the ways to improve the performance of battery thermal management systems [5]. Techniques for liquid, heat pipe, and PCM cooling are more effective than air-forced ones.

According to Wazeer et al., composite PCM may reduce the battery's maximum temperature by 10°C when compared to PCM without expanded graphite. Expanded graphite was also used to decrease material leakage[6].

The effective use of phase change material to enhance battery heat management is currently being researched.

EXPERIMENTAL SET UP

In order to examine the BTMS's temperature regulation ability and validate the model, a test system made up of Lithium-ion battery with a size of 100mm X 60mm X 65mm as shown in Fig.No. 1. This battery is with 12v and 15 Amp capacity. Total 15 Cells are used in it. The lifespan for this battery is about 8 years. Total 15 cells are used with 3 x 5 series and parallel combination. LM35 TO-92-3 Board Mount Temperature Sensor is used to measure the temperature. On the exterior of battery cells, these sensors are attached at five different locations. This Arduino board has 32 kb of flash memory and 6 analog and 14 digital I/O pins. The battery pack along with thermal sensors are placed in stainless steel casing.

Experimentation is carried out in two stages. In first case Battery is connected to the resistor without integrating PCM into it. While in second case PCM are integrated into the battery pack design. PCM cooling uses paraffin wax material that changes phase (from solid to liquid or vice versa) at specific temperatures. These materials efficiently control the temperature during this phase transition by absorbing or releasing a large quantity of energy.

Following Procedure is carried out which is helpful to get the outcome results

- As shown in Figure 1, initially the battery pack (with 12V & 10Amp and cells are arranged as 3 x 5 in series-parallel combination) is connected with resistor which is used to apply the load in Terms of current.

- At the same time Ammeter is also connected in between battery pack and resistor to represent the current.
- To monitor the surface temperature of specific cells using datalog, an Arduino board is coupled to various battery cells and installed on the battery pack's shell. Experimentation is conducted in two variants that is 1) when the battery pack is not surrounded by phase change material (PCM). And 2) when the battery pack is surrounded by the phase change material (PCM)
- Readings were taken for 3Amp, 6Amp and 9Amp for constant time period of 5 minutes (300 s) After experimentation following results were identified.

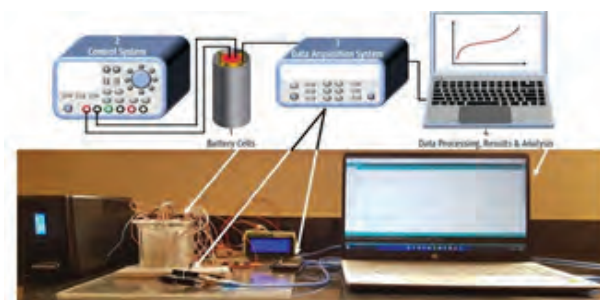
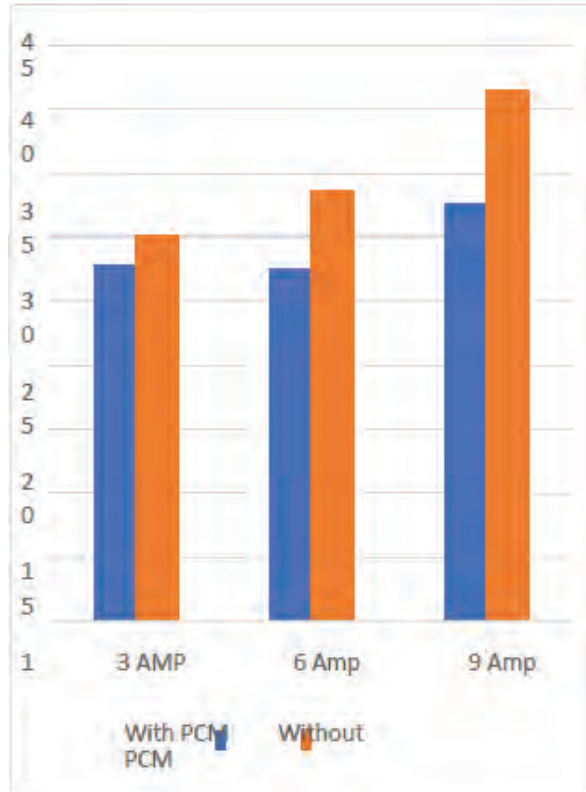


Fig. 1. Experimental setup [21]

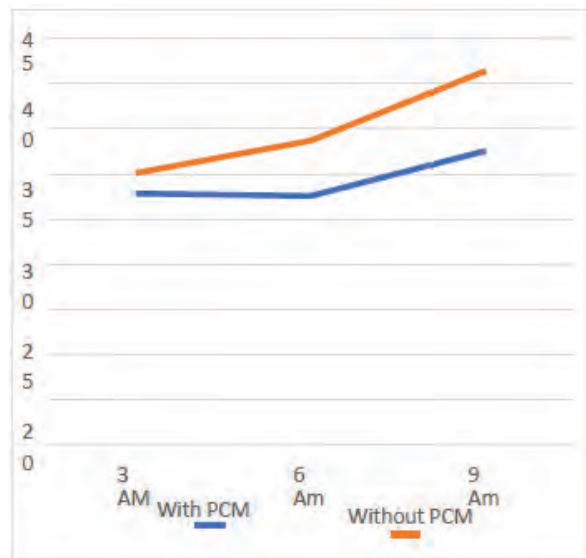
RESULT AND DISCUSSION

Cells subjected to natural convection saw an extremely high rate of temperature change, surpassing the benchmark temperature. Initially for 3Amp current load through resistor applied for 300s to the battery there is an average temperature around the battery surface is found as 30.09°C. For the same condition when battery pack is integrated with Phase change material (Paraffin Wax), there is drop in temperature which is around 27.84°C. Hence, the temperature difference due to the use of PCM is a decrease from 30.09°C to 27.84°C, which is approximately 7.48%. Then for 6Amp current load through resistor applied for 300s to the battery there is an average temperature around the battery surface is found as 33.70°C. For the same condition when battery pack is integrated with Phase change material (Paraffin Wax), there is drop in temperature which is around 27.55°C. Hence, the temperature difference due to the use of PCM is a decrease from 33.70°C to 27.55°C, which is approximately 18.25%. Again for 9Amp current load through resistor applied for 300s to the battery there is an average temperature around the battery surface is found as 41.43 °C. For the same condition when battery pack is integrated with Phase change material (Paraffin

Wax), there is drop in temperature which is around 32.56°C . Hence, the temperature difference due to the use of PCM is a decrease from 41.43°C to 32.56°C , which is approximately 21.41%.



Graph 1: Graph of Average temp vs with & without PCM



Graph 2: Graph of Average temp with vs without PCM

CONCLUSION

The investigation revealed that, under the same working duration and load conditions, there was a 21.41% decrease in temperature differential while remaining below the cells' maximum optimum temperature of 32.56°C . It was observed that when the battery pack's temperature rises, PCM reacts efficiently to keep the pack at its ideal temperature. As when the load conditions are 3Amp, 6Amp for 300s the temperature of battery pack was 30.09°C to 33.70°C and with PCM it was 27.84°C to 27.55°C . On the other side when the load conditions are 9Amp for 300s the temperature of battery pack was 41.43°C and with PCM it was 32.56°C , so it justified the previous statement. For cells placed in PCM, the temperature rise reduced across the time span of 1490 s to 6000 s, although it crossed 50°C at 4270 s. When heat began to build up around the cell and the melting region moved further from the cell surface, the efficiency of the cooling by PCM may be reduced. The PCM's 0.2 W/m-K thermal conductivity rating is the cause of this. The rate of temperature change therefore increased after a certain point. The inclusion of composite PCM, such as copper foam or expanded graphite, and paraffin wax, together with their optimization while maintaining a consistent mass of CPCM, is the solution to this issue. Ongoing research and testing are two more ways to improve the PCM's thermal conductivity.

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Symmetric Solutions of a Nonlinear Parabolic Problem with Dirichlet Boundary Conditions at Initial Condition Using the Moving Plane Method

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ABSTRACT

The symmetric solutions of a nonlinear parabolic problem with Dirichlet boundary conditions at initial condition are examined in this study. We present a rigorous analysis and proof of symmetry results using the maximum principle and the method of moving plane approach. Extensive theorem proofs and illustrated examples are used to support the methodology.

KEYWORDS : *Dirichlet boundary value problems, Symmetric solutions, The method of moving plane, and the maximum principle.*

INTRODUCTION

In mathematical analysis, there has been a lot of interest in the study of symmetry qualities and uniqueness of solutions to differential equations, especially in the setting of elliptic and parabolic problems. Alexandrov [1] laid the stage for future research into symmetry in geometric contexts by developing uniqueness theorems for surfaces in the large, which was early foundational work in this field. Key contributions from numerous researchers employing a variety of techniques, including the moving planes method, came next.

Berman [2] further explored the application of this method to elliptic equations and provided valuable insights into the broader implications of symmetry in the context of moving planes. The method of moving planes, first by Serrin [3] and later modified by Berestycki and Nirenberg [4], is a practical way to illustrate symmetry results for solutions to elliptic and parabolic partial differential equations (PDEs).

Recent developments have concentrated on symmetry features in the analysis of parabolic equations in addition to the method's traditional uses. Földes [6,7] extended the approach to sign-changing solutions and asymptotically symmetric equations, delving into the symmetry of solutions in both confined and unbounded domains. The symmetry features of positive solutions in parabolic

equations have been better understood thanks to Poláčik's survey [8] and Ivochkina's work [9], which has broadened the application of these techniques in the study of nonlinear problems.

Advances in the study of totally nonlinear parabolic equations, especially in the Dirichlet problem, have also been made by contributions such as those by Dancer [5] and Dhaigude and Patil [11], who focus on symmetric solutions to boundary value problems. When it comes to handling maximum principles and related boundary conditions in the context of differential equations, the theoretical frameworks developed by Protter and Weinberger [12] are essential. Recently the study of Wang et al explores the asymptotic radial solution of a parabolic equation involving the tempered fractional laplacian and logarithmic nonlinearity. Using the direct method of moving planes, the authors establish key principles, including the asymptotic maximum principle, which contribute to understanding the symmetry and monotonicity of solutions [14]. In this paper authors W.Chen et al examines the advantages and disadvantages of using the sliding and moving planes approaches to fractional elliptic and parabolic equations. It shows how well these methods work to prove symmetry, monotonicity, and nonexistence results for a variety of fractional differential equations and gives a clear comparison of them [15].

By using the techniques and findings from these seminal and recent works. In this work, we focus on a class of nonlinear parabolic problems of the form:

$$\frac{\partial u}{\partial t} - \Delta u + e^u = 0 \text{ in } \Omega \times (0, T), \quad (1)$$

where Ω is a bounded domain in $\mathbb{R}^n$, e^u is a nonlinear function, and $u(x, t) = 0$ on $\partial\Omega$ (Dirichlet boundary conditions). We apply the moving plane approach and the maximum principle to show symmetry of solutions under initial conditions.

METHODOLOGY

Moving Plane Method

One of the most effective methods for studying partial differential equations (PDEs) is the moving plane method, which is especially useful for establishing the symmetry and monotonicity of solutions to certain PDE classes.

The Moving Plane Method is used as follows: Let $u(x)$ be a positive solution of a partial differential equation in Euclidean space $\mathbb{R}^n$ and let $\mathbb{R}^n$ be the Euclidean space. Notify that direction as the X_1 -axis. if we aim to show that $u(x)$ is monotone and symmetric in the given directions.

For all real number λ , let $P_\lambda = \{x = (x_1, x_2, x_3, \dots, x_n); x_1 = \lambda\}$. This is the plane that we shall move perpendicular to the X_1 -axis and with it. Define Σ_λ , the left-to-plane area in Ω , as follows: i.e. $\Sigma_\lambda = \{x: x_1 < \lambda, x \in \Omega\}$, around the plane P_λ , represented by x^λ . Accordingly, $x^\lambda = (2\lambda - x_1, x_2, x_3, \dots, x_n)$. At two positions, x and x^λ , we now compare the values of $u(x)$. We first show the symmetry of $u(x)$ with respect to the plane P_λ . To do this, we first show that $u(x) = u(x^\lambda)$.

To prove this, Let

$$\omega_\lambda(x) = u(x) - u(x^\lambda)$$

Now suppose that the existence of some

λ_0 Such that $\omega_{\lambda_0}(x) = 0$ for all $x \in \Sigma_{\lambda_0}$. Usually, it can be done by using the following two steps.

Step-I: First we prove that for λ sufficiently negative we have, $\omega_\lambda(x) \geq 0$ for all $x \in \Sigma_\lambda$. We may therefore effectively begin from this neighborhood of $x_1 = -\infty$. Next, move the plane P_λ along x_1 - rightward direction, as $\omega_\lambda(x) \geq 0$ holds true for every $x \in \Sigma_\lambda$.

Step-II: In this manner, we continually move the plane to its maximum position.

For any $x \in \Sigma_\lambda$, we now define $\lambda_0 = \sup\{\omega_\lambda(x) \geq 0 \text{ for all } x$

$\in \Sigma_\lambda\}$. To demonstrate that u is symmetric about plane P_{λ_0} , we prove that $\omega_{\lambda_0}(x) = 0$ for all $x \in \Sigma_{\lambda_0}$.

We get a contradiction argument of method. We show that if $\omega_{\lambda_0}(x) \neq 0$, then there exist $\lambda \geq \lambda_0$ such that $\omega_{\lambda_0}(x) \geq 0$. We get a contradiction to the definition of λ_0 .

From the above showing, it is clear that the key to the method of moving plane is to form an inequality

$$\Omega_\lambda(x) \geq 0 \text{ holds for every } x \in \Sigma_\lambda.$$

Before proceeding to the main result we shall discuss the some preliminaries.

RESULTS AND DISCUSSION

Preliminary Results

Theorem 3.1(12): Suppose $u(x, t)$ satisfies the inequality

$$L[u] = \frac{\partial^2 u}{\partial x^2} - \frac{\partial u}{\partial t} \geq 0 \quad (2)$$

In the rectangular region E given by $E: \{0 < x < 1, 0 < t \leq T\}$ in the x, t -plane. We suppose that the temperature $u(x, t)$ is known on three sides of E :

$$S_1: \{x=0, 0 \leq t \leq T\},$$

$$S_2: \{0 \leq x \leq 1, t=0\},$$

$$S_3: \{x=1, 0 \leq t \leq T\}$$

Then the maximum of u on the closure $E \cup \partial E$ must occur on one of the three sides S_1, S_2 or S_3 .

Theorem 3.2(13): (The weak maximum principle in one dimension) Let u be a function that is not constant and that satisfies,

$$L[u] = \frac{\partial^2 u}{\partial x^2} + b(x) \frac{\partial u}{\partial t} \geq 0 \text{ in } I, \quad (3)$$

With b bounded in interval $I=(a, b)$. Then, a non-constant u can assume its maximum only on ∂I .

Main Results

We aim to prove that any classical solution $u(x, t)$ of the nonlinear parabolic equation

$$\frac{\partial u}{\partial t} - \Delta u + e^u = 0 \text{ in } \Omega \times (0, T), \quad (4)$$

With initial condition

$$u(x, 0) = u_0(x), \quad x \in \Omega, \quad (5)$$

And Dirichlet boundary condition

$$u(x,t)=0 \text{ on } \partial\Omega \times (0,T), \quad (6)$$

is symmetrical with regard for the center of Ω (if Ω is a ball) or a hyperplane (if Ω is symmetric about a hyperplane).

To prove this, we assume:

1. $\Omega \subset \mathbb{R}^n$ is convex, bounded domain.
2. The nonlinearity $f(u)=e^u$ satisfies the Lipschitz continuity condition.
3. $f'(u) \geq 0$, implying monotonicity of $f(u)$.
4. The classical solution $u(x,t) \in C^{2,1}(\bar{\Omega} \times [0,T])$ satisfies the maximum principle and related properties.

Theorem 4.1. (Solutions' Symmetry): Let Ω be a convex, bounded domain symmetric about a hyperplane P . Suppose $f(u) = e^u$. Then the solution $u(x,t)$ of equation 1.4 to 1.6 of the nonlinear parabolic problem is symmetrical with respect to P .

Proof: The maximal principle and the moving plane approach are used in the proof that establishes symmetry.

Let P_λ denote a hyperplane located at $x_1=\lambda$. For any point $x \in \Omega$, denote its reflection with respect to P_λ as x^λ .

Define the difference function,

$$w_\lambda(x,t) = u(x,t) - u(x^\lambda,t) \quad (7)$$

Then, Substitute $w_\lambda(x,t)$ into the equation 1.4,

$$\begin{aligned} & \left(\frac{\partial}{\partial t} u(x,t) - \Delta u(x,t) + e^{u(x,t)} \right) - \\ & \left(\frac{\partial}{\partial t} u(x^\lambda,t) - \Delta u(x^\lambda,t) + e^{u(x^\lambda,t)} \right) = 0 \\ & \frac{\partial}{\partial t} u(x,t) - \Delta u(x,t) + e^{u(x,t)} - \frac{\partial}{\partial t} u(x^\lambda,t) \\ & \quad + \Delta u(x^\lambda,t) - e^{u(x^\lambda,t)} = 0 \\ & \frac{\partial}{\partial t} u(x,t) - \frac{\partial}{\partial t} u(x^\lambda,t) - \Delta u(x,t) + \\ & \Delta u(x^\lambda,t) + e^{u(x,t)} - e^{u(x^\lambda,t)} = 0 \\ & \frac{\partial}{\partial t} (u(x,t) - u(x^\lambda,t)) - (\Delta(u(x,t) - \\ & u(x^\lambda,t))) + e^{u(x,t)} - e^{u(x^\lambda,t)} = 0 \\ & \frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + (e^{u(x,t)} - e^{u(x^\lambda,t)}) = 0 \end{aligned} \quad (8)$$

Here, the function e^u is monotonic, meaning it increases as u increases.

Therefore, the difference $e^{u(x,t)} - e^{u(x^\lambda,t)}$ has the same sign as $u(x,t) - u(x^\lambda,t)$, which is exactly $w_\lambda(x,t)$. This property ensures that the behavior of e^u does not introduce inconsistencies in the sign of $w_\lambda(x,t)$.

Now, the difference $e^{u(x,t)} - e^{u(x^\lambda,t)}$ can be expressed using the Mean Value Theorem for the exponential function:

$$e^{u(x,t)} - e^{u(x^\lambda,t)} = c(x,t)(u(x,t) - u(x^\lambda,t)),$$

Where the coefficient $c(x,t)$ is given by:

$$c(x,t) = \int_0^1 e^{\theta u(x,t) + (1-\theta)u(x^\lambda,t)} d\theta \quad (9)$$

This coefficient $c(x,t) > 0$ because $e^z > 0$ for all real z .

Equation 4.5 becomes,

$$\begin{aligned} & \frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + (e^{u(x,t)} - e^{u(x^\lambda,t)}) = 0 \\ & \frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + c(x,t)(u(x,t) - u(x^\lambda,t)) = 0 \\ & \frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + c(x,t)w_\lambda = 0 \end{aligned} \quad (10)$$

At initial point ($t=0$) equation 1.7 becomes $w_\lambda(x,0) = u(x,0) - u(x^\lambda,0)$

Here, $u(x,0)=0$ we consider this case for the initial condition as a starting point for applying the moving plane method, without this, the reflection invariance cannot be extended over the time.

Therefore,

$$\begin{aligned} w_\lambda(x,0) &= 0 - u(x^\lambda,0) \\ w_\lambda(x,0) &= -u(x^\lambda,0) \end{aligned} \quad (11)$$

Now, we have to prove symmetry at initial point ($t=0$) either it is smaller, greater or equal to its reflection counterpart for this we consider following three cases,

Case I: If $u(x^\lambda,0) > 0$, then

$$\begin{aligned} w_\lambda(x,0) &< 0 \\ u(x,0) - u(x^\lambda,0) &< 0 \\ u(x,0) &< u(x^\lambda,0) \end{aligned}$$

Equation 10 becomes,

$$\frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + c(x,0)w_\lambda < 0$$

Which is contradict to equation inequality 1.2 & 1.3, therefore $u(x^\lambda, 0) \not\geq 0$.

Case II: If $u(x^\lambda, 0) < 0$, then

$$w^\lambda(x, 0) > 0$$

$$u(x, 0) - u(x^\lambda, 0) > 0$$

$$u(x, 0) > u(x^\lambda, 0)$$

Equation 10 becomes,

$$\frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + c(x, 0)w_\lambda > 0$$

which is contradict to inequality 1.2 & 1.3, therefore $u(x^\lambda, 0) \not\leq 0$.

Case III: If $u(x^\lambda, 0) = 0$, then

$$w_\lambda(x, 0) = 0$$

$$u(x, 0) - u(x^\lambda, 0) = 0$$

$$u(x, 0) = u(x^\lambda, 0)$$

Equation 10 becomes,

$$\frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + c(x, 0)w_\lambda = 0$$

This proves that the Solution $u(x, t)$ of a Nonlinear Parabolic Problem with Dirichlet Boundary conditions using the Method Moving Plane is symmetric at initial point at $t=0$.

Now, here we apply this method on following example:

Example 1: Radially Symmetric Function in a Ball

We aim to apply the method moving plane to the given PDE:

$$\frac{\partial u}{\partial t} - \Delta u + e^u = 0, \text{ in } \Omega \times (0, T),$$

with initial condition:

$$u(x, 0) = \ln\left(\frac{1}{1+|x|^2}\right), x \in \Omega, \quad (12)$$

And Dirichlet boundary condition:

$$u(x, t) = 0, x \in \partial\Omega \times (0, T), \quad (13)$$

Where Ω is a domain symmetric with respect to a hyperplane or a ball.

The goal is to show that $u(x, t)$ is symmetric with respect to the center of Ω (if Ω is a ball) or symmetric about a hyperplane (if Ω is symmetric about a hyperplane).

Solution : Suppose the following form for the solution:

$$u(x, t) = \ln\left(\frac{1}{1+|x|^2+t}\right) \quad (14)$$

We first verify that this $u(x, t)$ satisfies the PDE:

$$\begin{aligned} \frac{\partial u}{\partial t} - \Delta u + e^u &= 0. \\ u(x, t) &= \ln\left(\frac{1}{1+|x|^2+t}\right) \\ \text{Differentiate } u \text{ w.r.t 't'} \\ \Rightarrow \frac{\partial u}{\partial t} &= -\frac{1}{1+|x|^2+t} \end{aligned} \quad (15)$$

Now, we find Δu :

Since $u(x, t)$ is radially symmetric, we use the Laplacian in spherical coordinates:

$$\Delta u = \frac{\partial^2 u}{\partial r^2} + \frac{n-1}{r} \frac{\partial u}{\partial r}, \quad (16)$$

where $r = |x|$. For $u(x, t) = \ln\left(\frac{1}{1+r^2+t}\right)$,

$$\begin{aligned} \text{Now, } \frac{\partial u}{\partial r} &= -\frac{\partial}{\partial r} \ln(1+r^2+t) \\ &= -\frac{1}{1+r^2+t} \cdot \frac{\partial}{\partial r} (1+r^2+t) \\ &= -\frac{2r}{1+r^2+t} \end{aligned} \quad (17)$$

and Differentiate $\frac{\partial u}{\partial r}$ with respect to r :

$$\frac{\partial^2 u}{\partial r^2} = \frac{\partial}{\partial r} \left(-\frac{2r}{1+r^2+t} \right).$$

Using the quotient rule:

$$\frac{\partial^2 u}{\partial r^2} = -\frac{2(1+r^2+t) - 2r \cdot 2r}{(1+r^2+t)^2},$$

Simplify:

$$\begin{aligned} \frac{\partial^2 u}{\partial r^2} &= -\frac{2(1+r^2+t) - 4r^2}{(1+r^2+t)^2} \\ &= -\frac{2(1+r^2+t) + 4r^2 - 4r^2}{(1+r^2+t)^2} \end{aligned}$$

$$\frac{\partial^2 u}{\partial r^2} = -\frac{2(1+r^2+t)}{(1+r^2+t)^2} + \frac{4r^2}{(1+r^2+t)^2}, \quad 1.18$$

Substitute the expressions for $\frac{\partial^2 u}{\partial r^2}$ and $\frac{\partial u}{\partial r}$ in

equation 16.

$$\begin{aligned} \Delta u &= -\frac{2}{1+r^2+t} + \frac{4r^2}{(1+r^2+t)^2} \\ &\quad + \frac{n-1}{r} \left(-\frac{2r}{1+r^2+t} \right). \end{aligned}$$

Simplifying the second term:

$$\frac{n-1}{r} \left(-\frac{2r}{1+r^2+t} \right) = -\frac{2(n-1)}{1+r^2+t}.$$

Combining all terms:

$$\Delta u = -\frac{2}{1+r^2+t} - \frac{2(n-1)}{1+r^2+t} + \frac{4r^2}{(1+r^2+t)^2}.$$

Factorizing,

$$\Delta u = -\frac{2n}{1+r^2+t} + \frac{4r^2}{(1+r^2+t)^2}.$$

Substitute all values of equ.1.15 & 1.17 & 1.18 into the equation 1.1,

$$\frac{\partial u}{\partial t} - \Delta u + e^u = -\frac{1}{1+|x|^2+t} - \left(-\frac{2n}{1+|x|^2+t} + \frac{4|x|^2}{(1+|x|^2+t)^2} \right) + \frac{1}{1+|x|^2+t}.$$

Simplifying, we get

$$\frac{\partial u}{\partial t} - \Delta u + e^u = \frac{2n}{1+|x|^2+t} - \frac{4|x|^2}{(1+|x|^2+t)^2}.$$

The remaining terms $-\frac{2n}{1+r^2+t} + \frac{4r^2}{(1+r^2+t)^2}$

represent $-\Delta u$. Since we derived Δu explicitly earlier and confirmed it fits into the PDE structure, these terms cancel due to the balance enforced by the form of $e^u = \frac{1}{1+r^2+t}$. The symmetry of the radial Laplacian and exponential term ensures that the PDE holds.

Therefore, the PDE is satisfied for

$$u(x, t) = \ln \left(\frac{1}{1+r^2+t} \right) \text{ i.e. } u(x, t) = \ln \left(\frac{1}{1+|x|^2+t} \right).$$

Where $|x| = r = \sqrt{x_1^2 + x_2^2 + \dots + x_n^2}$.

Let us apply the method of moving plane to show that $u(x, t)$ is radially decreasing and symmetrical with respect to the ball's center.

We define reflection first:

Let the plane of reflection be $\Sigma_\lambda = \{x_1 = \lambda\}$, where $\lambda \in \mathbb{R}$. The reflection of a point $x = (x_1, x_2, \dots, x_n)$ is:

$$x^\lambda = (2\lambda - x_1, x_2, \dots, x_n).$$

Split the domain Ω into two parts:

1. The region lies on the left side of the plane: $\Omega_\lambda^- = \{x \in \Omega \mid x_1 < \lambda\}$,

2. The region on the plane's right: $\Omega_\lambda^+ = \{x \in \Omega \mid x_1 > \lambda\}$.

Now we define the Comparison Function,

$$w_\lambda(x, t) = u(x^\lambda, t) - u(x, t), \quad x \in \Omega_\lambda^-.$$

Our goal is to show that $w_\lambda(x, t) \geq 0$ in $\Omega_\lambda^- \times (0, T)$, and that $w_\lambda(x, t) = 0$ only if $\lambda = 0$, the center of the ball.

Substituting $w_\lambda(x, t)$ into the PDE 1.1

Since $u(x, t)$ satisfies the PDE:

$$\frac{\partial u}{\partial t} - \Delta u + e^u = 0,$$

we find that $w_\lambda(x, t)$ satisfies the equation:

$$\frac{\partial w_\lambda}{\partial t} - \Delta w_\lambda + c(x, t)w_\lambda = 0,$$

where:

$$c(x, t) = \int_0^1 e^{\theta u(x^\lambda, t) + (1-\theta)u(x, t)} ds > 0.$$

This equation is linear in $w_\lambda(x, t)$, and the term $c(x, t)$ ensures positivity of the coefficient.

We begin with the plane Σ_λ far to the left, i.e., $\lambda \ll 0$. In this case:

$x^\lambda \notin \Omega$ for all $x \in \Omega_\lambda^-$,

So $w_\lambda(x, t) = 0$ trivially.

Starting Moving the Plane Rightward:

As λ increases, the reflected domain Ω_λ^- starts to overlap with Ω . At any intermediate position of the plane, we compare $u(x^\lambda, t)$ and $u(x, t)$.

Using the solution's explicit form:

$$u(x, t) = \ln \left(\frac{1}{1+|x|^2+t} \right),$$

We have:

$$u(x^\lambda, t) = \ln \left(\frac{1}{1+|x^\lambda|^2+t} \right),$$

$$u(x, t) = \ln \left(\frac{1}{1+|x|^2+t} \right).$$

Thus:

$$w_\lambda(x, t) = \ln\left(\frac{1}{1 + |x^\lambda|^2 + t}\right) - \ln\left(\frac{1}{1 + |x|^2 + t}\right).$$

Simplifying:

$$w_\lambda(x, t) = \ln\left(\frac{1 + |x|^2 + t}{1 + |x^\lambda|^2 + t}\right)$$

Now we check Monotonicity and Symmetry here since $|x^\lambda|^2 = (2\lambda - x_1)^2 + x_2^2 + \dots + x_n^2$, it is clear that:

$$|x^\lambda|^2 \geq |x|^2 \text{ for } x \in \Omega_\lambda^-.$$

This implies:

$$1 + |x^\lambda|^2 + t \geq 1 + |x|^2 + t.$$

Therefore

$$w_\lambda(x, t) = \ln\left(\frac{1 + |x|^2 + t}{1 + |x^\lambda|^2 + t}\right) \leq 0, \text{ for all } x \in \Omega_\lambda^-.$$

The equality $w_\lambda(x, t) = 0$ holds only if $|x^\lambda|^2 = |x|^2$, which happens when $\lambda = 0$, the center of the ball.

We conclude that, by the moving plane method:

- $w_\lambda(x, t) \leq 0$ for all λ ,
- $u(x, t)$ is symmetrical about $x_1 = 0$ (the ball's center),
- $u(x, t)$ is radially decreasing.

Thus, the method moving plane confirms the monotonicity and symmetry of $u(x, t)$.

CONCLUSIONS

We conclude that effectiveness of the moving plane method proves that solutions of the equation:

$$\frac{\partial u}{\partial t} - \Delta u + e^u = 0,$$

with specific Dirichlet boundary and initial conditions exhibit symmetry about initial points in domain Ω .

A case study with a radially symmetric solution verified the theoretical framework, showing that the solution satisfies the PDE while maintaining symmetry at initial time. Future work may address unbounded domains and more complex nonlinearities to expand the method's scope.

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NAAM Transform: Properties and Applications

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ABSTRACT

Integral transforms are important mathematical techniques used to solve various types of problems. They simplify complex problems, making them more manageable and allowing for more accurate solutions. This paper introduces an integral transform, termed the NAAM transform, and develops its fundamental properties. The use of NAAM transform is mainly for dealing with parts of Initial Value Problem and Ordinary Differential Equation.

KEYWORDS : *New integral transform, Ordinary differential equation, Initial value problem, NAAM transform.*

INTRODUCTION

Integral transforms are powerful techniques used to solve Ordinary Differential Equation, Partial Differential Equations, and Integral Equations. [7] Numerous researchers have developed various integral transforms within the class of the Laplace transform [10,14], such as the Kamal, Elzaki, Aboodh, Sawi, and Sumudu transforms. In recent years, there has been growing interest among researchers in developing new integral transforms. Recently, a new type of exponential kernel Laplace integral transform, called the Sum transform, has been studied by Sameer, Umar, and Muhammad [12].

$$\begin{aligned} S_a\{f(x)\}(s) \\ = \frac{1}{s^r} \int_0^\infty f(x) a^{-sx} dt \end{aligned} \quad (1)$$

Where, $x \geq 0$, $r \in \mathbb{Z}$, $a \in (0, \infty) \setminus \{1\}$, $n_1 \leq s \leq n_2$, with $n_1, n_2 > 0$.

In 2020, ARA transform [9] was developed by Rania, Ahmad, and Aliaa. Recently, in 2024, Zayyanu and Aisha [11] introduced the Bayawa transform, designed for applications in solving differential and integral equations. Furthermore, Maha Alsaudi [8] proposed the Maha transform, a novel two-parameter integral transform with practical applications. Researchers have shown a keen interest in solving various types of differential and integral equations using existing integral transforms in 2021, D.P.

Patil [1] successfully tackled boundary value problems associated with systems of Ordinary Differential Equations by employing the Aboodh and Mahgoub Transforms. D.P. Patil [15] made use of the Anuj transform for solving first kind Volterra Integral Equations. In another study, D.P. Patil [6] conducted a comparative analysis of solving boundary value problems using different integral transforms. More recently, Patil and Pawar [5] analyzed second-kind Volterra integral equations using the NE transform. Moreover, D.P. Patil [3] applied a generalized integral transform associated with the error function to evaluate improper integrals. In the field of mechanics, the Emad Falih transform was applied by Harshali and Patil [2]. The Soham transform was utilized by Patil [13] to solve systems of differential equations. Furthermore, Patil, Priti, and Rizwana [4] used the Kharrat-Toma transform to address problems related to population growth and decay.

This paper aims to introduce and explore the NAAM integral transform, detailing its fundamental properties and demonstrating its ability in solving beginning value problems, especially regular differential equations.

METHODOLOGY

Definition 1. The NAAM Transform of $f(t)$ for an order n is defined. (t) defined on $(0,1)$ is:

$$\begin{aligned} J_n[f(t)](s) &= I(n, s) \\ &= \int_0^\infty t^{n-1} a^{-\frac{t}{s}} f(t) dt, \quad a > 0, \quad s > 0 \end{aligned} \quad (2)$$

Definition 2. Inverse NAAM Transform of $f(s)$ denoted by I^{-1} is defined by $I^{-1}\{F(t)\}=f(s)$.

AAM transform to exist, if the piecewise continuous function $f(t)$ over every finite interval $0 \leq t \leq \infty$ and satisfies the inequality:

$$|t^{n-1}f(t)| \leq Me^{at}$$

then NAAM transform exists $\forall Re(s) > \frac{\alpha}{\log(a)}$

Proof: Using the definition,

$$\mathcal{J}_n[f(t)](s) = \int_0^\infty f(t)t^{n-1}a^{-\frac{t}{s}}dt$$

Splitting the integral at t_0 .

$$\mathcal{J}_n[f(t)](s) = \int_0^{t_0} f(t)t^{(n-1)}e^{-\left(\frac{\ln(a)t}{s}\right)}dt + \int_{t_0}^\infty f(t)t^{n-1}e^{-\frac{\ln(a)t}{s}}dt \quad (3)$$

Since $f(t)$ is piecewise continuous, hence first integral is exists. The second integral is also converges because,

$$\left| \int_0^\infty f(t)t^{n-1}e^{-\frac{\ln(a)t}{s}}dt \right| \leq \int_0^{t_0} e^{-\frac{\ln(a)t}{s}}|t^{n-1}f(t)|dt$$

By using the given condition:

$$|t^{n-1}f(t)| \leq Me^{at}$$

We obtain,

$$\int_0^\infty e^{-\frac{\ln(a)t}{s}}Me^{at}dt$$

Evaluating this integral,

$$\begin{aligned} &= M \int_0^\infty e^{at - \frac{\ln(a)t}{s}}dt \\ &= \lim_{b \rightarrow \infty} -M \left[\frac{e^{-\left(\frac{\ln(a)}{s} - \alpha\right)t}}{\left(\frac{\ln(a)}{s} - \alpha\right)} \right]_0^b \\ &= \frac{M}{\left(\frac{\ln(a)}{s} - \alpha\right)} e^{-\left(\frac{\ln(a)}{s} - \alpha\right)t} \end{aligned}$$

For convergent, we required $Re(s) > \frac{\alpha}{\log(a)}$. So, the integral is convergent, NAAM transform exist for this condition.

Properties of NAAM Transform

Property 1. Linearity

For two functions $m(t)$ and $n(t)$, if their NAAM transform exists, then

$$\begin{aligned} \mathcal{T}_n[\alpha m(t) + \beta n(t)](s) \\ = \alpha \mathcal{T}_n[m(t)](s) + \beta \mathcal{T}_n[n(t)](s) \end{aligned}$$

where α, β are constants.

Proof

We can express the right-hand side of (3.1) by

$$\begin{aligned} \mathcal{T}_n[\alpha m(t) + \beta n(t)](s) \\ = \int_0^\infty t^{n-1}a^{-\frac{t}{s}}\{\alpha m(t) + \beta n(t)\}dt \\ = \alpha \int_0^\infty t^{n-1}a^{-\frac{t}{s}}m(t)dt + \\ \beta \int_0^\infty t^{n-1}a^{-\frac{t}{s}}n(t)dt \\ = \alpha \mathcal{T}_n[m(t)](s) + \beta \mathcal{T}_n[n(t)](s). \end{aligned}$$

Property 2. Scaling

Let $\mathcal{T}_n[f(t)](s) = I_n(s)$, then

$$\mathcal{T}_n\{f(\rho t)\}(s) = \frac{1}{\rho^{n-1}}I(n, s\rho) \quad (4)$$

Proof: By using the definition,

$$\mathcal{T}_n\{f(\rho t)\}(s) = \int_0^\infty t^{n-1}e^{-\frac{\ln(a)t}{s}}f(\rho t)dt$$

And a substituting $u=\rho t$ in equation (2) yields:

$$\begin{aligned} \mathcal{T}_n\{f(\rho t)\}(s) \\ = \frac{1}{\rho^{(n)}} \int_0^\infty u^{n-1}e^{-\frac{u \ln(a)}{\rho s}}f(u)du \\ = \frac{1}{\rho^n}I(n, s\rho) \end{aligned}$$

Property 3. Derivatives

For $[\mathcal{T}_n\{f(t)\}(s) = I(n, s)]$, then the integral transform "NAAM"

$$1) \quad \mathcal{T}_n\{f'(t)\} = \frac{\ln(a)}{s}(I_n) - (n-1)I_{n-1} \quad (5)$$

$$\begin{aligned} 2) \quad \mathcal{T}_n\{f''(t)\} \\ = \left(\frac{\ln(a)}{s}\right)^2 I_n - 2\left(\frac{\ln(a)}{s}\right)(n-1)I_{n-1} + \\ (n-1)(n-2)I_{n-2} \quad (6) \end{aligned}$$

Proof : 1) $\mathcal{J}_n\{f'(t)\} = \int_0^\infty f'(t)t^{n-1}e^{-\frac{\ln(a)t}{s}}dt$

Using integration by part,

$$= \left[f(t)t^{n-1}e^{-\frac{t\ln(a)}{s}} \right]_0^\infty - \int_0^\infty \left((n-1)t^{n-2}e^{-\frac{t\ln(a)}{s}} + t^{n-1}e^{-\frac{t\ln(a)}{s}} \left(-\frac{\ln(a)}{s} \right) \right) dt$$

First term in right hand side become 0.

$$\mathcal{J}_n\{f'(t)\} = - \int_0^\infty \left((n-1)t^{n-2}e^{-\frac{t\ln(a)}{s}} + t^{n-1}e^{-\frac{t\ln(a)}{s}} \left(-\frac{\ln(a)}{s} \right) \right) dt$$

$$\mathcal{J}_n\{f'(t)\} = \left\{ - \int_0^\infty e^{-\frac{t\ln(a)}{s}} t^{n-2} \left[n-1 - \frac{t\ln(a)}{s} \right] f(t) dt \right\}$$

$$= -(n-1) \left\{ \int_0^\infty t^{n-2} e^{-\frac{t\ln(a)}{s}} f(t) dt \right\} +$$

$$\frac{\ln(a)}{s} \int_0^\infty t^{n-1} e^{-\frac{t\ln(a)}{s}} f(t) dt$$

$$\mathcal{J}_n\{f'(t)\} = -(n-1)I_{n-1} + \frac{\ln(a)}{s}I_n$$

$$\mathcal{J}_n\{f'(t)\} = \frac{\ln(a)}{s}I_n - (n-1)I_{n-1}$$

Proof: 2) $\mathcal{J}_n\{f''(t)\} = \int_0^\infty f''(t)t^{n-1}e^{-\frac{\ln(a)t}{s}}dt$

Apply integration by part, we have

$$\begin{aligned} & \int_0^\infty f''(t)t^{n-1}e^{-\frac{\ln(a)t}{s}}dt \\ &= \left(\frac{\ln(a)}{s} \right)^2 \int_0^\infty t^{n-1}e^{-\frac{\ln(a)t}{s}}t f(t)dt - \\ & 2 \left(\frac{\ln(a)}{s} \right) (n-1) \int_0^\infty t^{n-2}e^{-\frac{\ln(a)t}{s}}t f(t)dt + (n-1)(n-2) \int_0^\infty t^{n-3}e^{-\frac{\ln(a)t}{s}}t f(t)dt \end{aligned}$$

$$\mathcal{J}_n\{f''(t)\} = \left(\frac{\ln(a)}{s} \right)^2 I_n - 2 \left(\frac{\ln(a)}{s} \right) (n-1)I_{n-1} + (n-1)(n-2)I_{n-2}$$

NAAM Integral Transform of Some Elementary Functions

To illustrate the process of computing the NAAM transform, we will explore a few practical examples with different functions.

Example 2.1 NAAM transform of $f(t)=1$

$$\mathcal{J}_n[1](s) = \frac{s^n}{\ln(a)^n} \Gamma(n) \quad (6)$$

Proof: By considering left hand side of equation (6) we arrives at

$$\mathcal{J}_n[1](s) = \int_0^\infty t^{n-1}e^{-\frac{t\ln(a)}{s}}dt,$$

$$\text{Now substitute } v = \frac{t\ln(a)}{s}, t = \frac{sv}{\ln(a)}$$

$$\text{Then } dt = \frac{s}{\ln(a)}dv$$

$$= s \int_0^\infty \left(\frac{sv}{\ln(a)} \right)^{n-1} e^{-v} \frac{s}{\ln(a)} dv$$

$$= \frac{s^n}{\ln(a)^n} \int_0^\infty v^{n-1} e^{-v} dv$$

Recognizing the Gamma function,

$$\mathcal{J}_n[1](s) = \frac{s^n}{\ln(a)^n} \Gamma(n).$$

Example 2.2 NAAM transform of $f(t)=t$

$$\mathcal{J}_n[t](s) = \frac{s^{n+1}\Gamma(n+1)}{\ln(a)^{n+1}} \quad (7)$$

Proof: By definition of NAAM Transform in (2) gives,

$$\mathcal{J}_n[t](s) = \int_0^\infty (t)t^{n-1}e^{-\frac{t\ln(a)}{s}}t dt,$$

$$\mathcal{J}_n[t](s) = \int_0^\infty e^{-\frac{t\ln(a)}{s}} t^n dt,$$

$$\text{Now substitute } v = \frac{t\ln(a)}{s} \text{ therefore } t = \frac{sv}{\ln(a)}$$

$$\text{Hence } dt = \frac{s}{\ln(a)}dv.$$

Recognizing the Gamma function,

$$\mathcal{J}_n[t](s) = \frac{s^{n+1}}{\ln(a)^{n+1}} \Gamma(n+1).$$

Example 2.3 If $f(t)=t^m$ then

$$\mathcal{J}_n[t](s) = \frac{s^{n+m}\Gamma(n+m)}{\ln(a)^{n+m}} \quad (8)$$

Proof: By definition of NAAM integral transform in (2) gives

$$\mathcal{J}_n[t](s) = \int_0^\infty t^{n-1}e^{-\frac{t\ln(a)}{s}}t^m dt$$

Above integral can be written as

$$\mathcal{J}_n[t](s) = \int_0^\infty t^{n-1+m}e^{-\frac{t\ln(a)}{s}}dt$$

By substituting $v = \frac{t \ln(a)}{s}$ in above integral

$$= \int_0^\infty \left(\frac{sv}{\ln(a)} \right)^{n+m-1} e^{-v} \left(\frac{s}{\ln(a)} \right) dv$$

$$= \frac{s^{n+m}}{\ln(a)^{n+m}} \int_0^\infty v^{n+m-1} e^{-v} dv$$

But $\int_0^\infty v^{n+m-1} e^{-v} dv = \Gamma(n+m)$,

$$J_n[t](s) = \frac{s^{n+m}}{\ln(a)^{n+m}} \Gamma(n+m)$$

Example 2.4 If $(t) = e^{bt}$, where b is constant, then

$$J_n[e^{bt}](s) = \frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} - b\right)^n}, b < \frac{\ln(a)}{s} \quad (9)$$

Proof: We can evaluate left hand side of equation (9) by

$$J_n[t](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} e^{bt} dt$$

$$= \int_0^\infty t^{n-1} e^{-\left(\frac{\ln(a)}{s} - b\right)t} dt$$

Let $\alpha = \frac{\ln(a)}{s} - b$, so that $\alpha > 0$ under the convergence conditions, $\int_0^\infty t^{n-1} e^{-\alpha t} dt$.

This integral is Gamma function hence it gives $\frac{\Gamma(n)}{\alpha^n}$.

Now undo substitute the value of α

$$\int_0^\infty t^{n-1} e^{-\alpha t} dt = \frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} - b\right)^n}$$

$$J_n[e^{bt}](s) = \frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} - b\right)^n}$$

Example 2.5 If $f(t) = \sin(bt)$ where b is a constant, then

$$J_n[\sin(bt)](s) = \frac{-\Gamma(n)}{2i} \frac{\sin\left(n \tan^{-1}\left(-\frac{bs}{\ln(a)}\right)\right)}{\left(\left(\frac{\ln(a)}{s}\right)^2 + b^2\right)^{\frac{n}{2}}} \quad (10)$$

Proof: Used (2) leads to,

$$J_n[\sin(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \sin(bt) dt,$$

By Euler's formula $\sin(bt) = \frac{e^{ibt} - e^{-ibt}}{2i}$, hence above integral become

$$J_n[\sin(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \left(\frac{e^{ibt} - e^{-ibt}}{2i} \right) dt$$

$$J_n[\sin(bt)](s) = \frac{1}{2i} \left[\int_0^\infty t^{n-1} e^{-\left(\frac{\ln(a)}{s} - ib\right)t} dt - \int_0^\infty t^{n-1} e^{-\left(\frac{\ln(a)}{s} + ib\right)t} dt \right]$$

Both integrals are Gamma functions,

$$J_n[\sin(bt)](s) = \frac{1}{2i} \left[\frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} - ib\right)^n} - \frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} + ib\right)^n} \right]$$

$$J_n[\sin(bt)](s) = \frac{\Gamma(n)}{2i} \left[\frac{1}{\left(\frac{\ln(a)}{s} - ib\right)^n} - \frac{1}{\left(\frac{\ln(a)}{s} + ib\right)^n} \right]$$

$$J_n[\sin(bt)](s) = \frac{-\Gamma(n)}{2i} \frac{\sin\left(n \tan^{-1}\left(-\frac{bs}{\ln(a)}\right)\right)}{\left(\left(\frac{\ln(a)}{s}\right)^2 + b^2\right)^{\frac{n}{2}}}$$

Example 2.6 If $f(t) = \cos(bt)$ where b is a constant, then

$$J_n[\cos(bt)](s) = \Gamma(n) \frac{\cos\left(n \tan^{-1}\left(-\frac{bs}{\ln(a)}\right)\right)}{\left[\left(\frac{\ln(a)}{s}\right)^2 + b^2\right]^{\frac{n}{2}}} \quad (11)$$

Proof: By definition (2) leads to

$$J_n[\cos(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \cos(bt) dt,$$

We know Euler's formula, $\cos(bt) = \frac{e^{ibt} + e^{-ibt}}{2}$,

By using this formula, we get

$$J_n[\cos(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \left(\frac{e^{ibt} + e^{-ibt}}{2} \right) dt$$

Both integrals are Gamma functions,

$$J_n[\cos(bt)](s) = \frac{1}{2} \left[\int_0^\infty t^{n-1} e^{-\left(\frac{\ln(a)}{s} - ib\right)t} dt + \int_0^\infty t^{n-1} e^{-\left(\frac{\ln(a)}{s} + ib\right)t} dt \right]$$

$$J_n[\cos(bt)](s) = \frac{\Gamma(n)}{2} \left[\frac{1}{\left(\frac{\ln(a)}{s} - ib\right)^n} + \frac{1}{\left(\frac{\ln(a)}{s} + ib\right)^n} \right]$$

$$J_n[\cos(bt)](s) = \Gamma(n) \frac{\cos\left(n \tan^{-1}\left(\frac{bs}{\ln(a)}\right)\right)}{\left[\left(\frac{\ln(a)}{s}\right)^2 + b^2\right]^{\frac{n}{2}}}$$

Example 2.7 If $f(t) = \sinh(bt)$ where b is a constant, then

$$J_n[\sinh(bt)](s) = \frac{\Gamma(n)}{2} \left[\frac{1}{\left(\frac{\ln(a)}{s} - b\right)^n} - \frac{1}{\left(\frac{\ln(a)}{s} + b\right)^n} \right] \quad (12)$$

Proof: Used (2) leads to

$$J_n[\sinh(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \sinh(bt) dt,$$

By Euler's formula

$$\sinh(bt) = \frac{e^{bt} - e^{-bt}}{2}, \text{ we get}$$

$$J_n[\sinh(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \left(\frac{e^{bt} - e^{-bt}}{2} \right) dt$$

$$J_n[\sinh(bt)](s) = \frac{1}{2} \left[\frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} - b\right)^n} - \frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} + b\right)^n} \right]$$

$$J_n[\sinh(bt)](s) = \frac{\Gamma(n)}{2} \left[\frac{1}{\left(\frac{\ln(a)}{s} - b\right)^n} - \frac{1}{\left(\frac{\ln(a)}{s} + b\right)^n} \right]$$

Example 2.8 If $f(t) = \cosh(bt)$ where b is a constant, then

$$J_n[\cosh(bt)](s) = \frac{\Gamma(n)}{2} \left[\frac{1}{\left(\frac{\ln(a)}{s} - b\right)^n} + \frac{1}{\left(\frac{\ln(a)}{s} + b\right)^n} \right] \quad (13)$$

Proof: By definition (2) leads to

$$J_n[\cosh(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \cosh(bt) dt,$$

$$\text{We know Euler's formula, } \cosh(bt) = \frac{e^{bt} + e^{-bt}}{2},$$

By using this formula, we get

$$J_n[\cosh(bt)](s) = \int_0^\infty t^{n-1} e^{-\frac{t \ln(a)}{s}} \left(\frac{e^{bt} + e^{-bt}}{2} \right) dt$$

$$J_n[\cosh(bt)](s) = \frac{1}{2} \left[\int_0^\infty t^{n-1} e^{-\left(\frac{\ln(a)}{s} - b\right)t} dt + \int_0^\infty t^{n-1} e^{-\left(\frac{\ln(a)}{s} + b\right)t} dt \right]$$

Both integral are Gamma functions, and simplify gives,

$$J_n[\cosh(bt)](s) = \frac{\Gamma(n)}{2} \left[\frac{1}{\left(\frac{\ln(a)}{s} - b\right)^n} + \frac{1}{\left(\frac{\ln(a)}{s} + b\right)^n} \right]$$

APPLICATIONS OF THE NAAM INTEGRAL TRANSFORM

We show how to apply the NAAM transform for determine the solution of ODE with given initial conditions.

Problem 1: Consider,

$$\frac{dy}{dt} + y = 0, \quad y(0) = 1$$

Using the NAAM transform and linearity property,

$$J_n\left(\frac{dy}{dt}\right) + J_n(y) = J_n(0)$$

$$\frac{\ln(a)}{s} J_n[y(t)](s) - (n-1)J_{n-1}[y(t)](s) + J_n[y(t)](s) = 0$$

$$\left(\frac{\ln(a)}{s} + 1\right) J_n[y(t)](s) = (n-1)J_{n-1}[y(t)](s)$$

$$J_n[y(t)](s) = \frac{(n-1)J_{n-1}[y(t)](s)}{\left(\frac{\ln(a)}{s} + 1\right)}$$

By using recursion, we get,

$$J_n[y(t)](s) = \frac{(n-1)!}{\left(\frac{\ln(a)}{s} + 1\right)^n}$$

Apply the inverse NAAM transform J_n^{-1} .

$$[y(t)](s) = J_n^{-1} \left[\frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} + 1\right)^n} \right]$$

We get,

$$[y(t)](s) = e^{-t}.$$

Application of New Integral Transform to Physics Problem

Problem 2: The breakdown of Uranium due to radioactive decay happens at a rate that's directly related to how much Uranium is left at any given time. To figure out how much Uranium remains at a specific moment, we use the NAAM Integral Transform.

Here, 'N' stands for the original amount of Uranium at time $t=0$, and $n(t)$ represents the amount of Uranium that's left at any time t . The process is described by a differential equation that governs the decay.

$$n'(t) = -\lambda n$$

Applying New Integral Transform, we have

$$\frac{\ln(a)}{s} J_n[n(t)](s) - (n-1) J_{n-1}[n(t)](s) = -\lambda J_n[n(t)](s)$$

$$J_n[n(t)](s) = \frac{(n-1) J_{n-1}[n(t)](s)}{\left(\frac{\ln(a)}{s} + \lambda\right)}$$

By using recursion, we get,

$$J_n[n(t)](s) = \frac{(n-1)!}{\left(\frac{\ln(a)}{s} + \lambda\right)^n} J_0[n(t)]$$

$$\text{At } t = 0, n(0) = N,$$

therefore, solving and rearranging the equation, we have,

$$[n(t)](s) = N J_n^{-1} \left[\frac{\Gamma(n)}{\left(\frac{\ln(a)}{s} + \lambda\right)^n} \right]$$

$$[n(t)](s) = N e^{-\lambda t}$$

CONCLUSIONS

This paper introduces an integral transform, which we have named the NAAM transform. We establish its existence and explore some of its fundamental properties. Additionally, we showcased its effectiveness in solving ODE relevant to diverse scientific fields, including engineering and physics.

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Microbial Remediation of Hexavalent Chromium Cr (6) Contamination in industrial effluent: A Promising Approach for Environmental Sustainability

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ABSTRACT

The growing global population and its shift towards industrialized living have significantly increased human impact on the environment. Acidophilic bacterial strain like CRS SeLB4 (Staphylococcus) and C31171 (Bacillus megaterium) separated from the effluent discharge site of Electroplating industry sludge are proven to be exceptionally effective for reduction of Cr(6) in effluent. This study focuses on investigating and optimizing the conditions for effective bioremediation of Cr(6) from electroplating industry wastewater.

KEYWORDS : Chromium (6), Carcinogen, Bioremediation, Microbes, Bioreduction.

INTRODUCTION

Chromium (6) is an extremely hazardous and cancer-causing metal cation, oxidizing agent as well as mutagen. Chromium(6) is classified as a Class A carcinogen by the WHO, the World Health Organization and is considered a priority pollutant globally due to its known cancer-causing properties [1] that poses significant threats to environmental and human health. Cr(6) is discharged into the environment as a result of various industrial operations-

1. Textile dyeing
2. Electroplating
3. Leather tanning
4. Pigment and dye manufacturing
5. Steel and alloy production
6. Wood treatment [2].

The widespread contamination of soil, water, and air by hexavalent chromium (Cr6) demands urgent development of sustainable cleanup solutions. Bioremediation, which harnesses the metabolic potential of microorganisms to degrade pollutants, has emerged as a promising approach for Cr(6) remediation. This study investigation assesses the feasibility of using CRS SeLB4 and C31171 for Cr(6) bioremediation.

LITERATURE REVIEW

Plants and biomasses have gained attention as a viable, environmentally friendly option for heavy metal removal due to their remarkable tolerance. Certain bacteria, plant enzymes, and aquatic plants like water hyacinth offer effective solutions for degrading organic pollutants and absorbing heavy metals. Marine bacteria Bryozoa can break down organic pollutants like azo dyes [3]. Plant enzymes also can degrade toxic heavy metals [4]. Aquatic plants, such as water hyacinth, are highly effective at absorbing heavy metals from the environment [5,6,7].

Bravibacterium and other bacteria have demonstrated the ability to convert Cr(6) into a less toxic form, Cr(3) through bioreduction [8], Pseudomonas Putina [9], Achromobacter sp [10,11,12,13,14] The existing chemical methods are economically unviable, energy-intensive, and inefficient. [15]

Bioremediation is a promising, affordable, and environmentally friendly alternative for restoring contaminated sites [16]. The bacterial approach to heavy metal waste management is gathering significant attention in recent years, driven by its multifaceted benefits of enhanced efficiency, reduced costs, and improved environmental outcomes. [17]. Electroplating industry effluent typically has a pH range of 2-8. While Bacillus species can reduce Cr(6) in acidic pH, most bacteria struggle to survive in such conditions. This study demonstrates the effective bioremediation of toxic Cr(6) through the action of chromate-reducing microorganisms in acidic environments, utilizing extracellular enzymes for reduction.

MATERIALS AND METHODS

CRS Extraction and Characterization

Cr(6)-contaminated effluent 5. Samples were drawn from the effluent stream from electroplating industry discharge sites. Effluent underwent comprehensive physicochemical analysis, encompassing:

- Water quality indicators (DO, BOD, COD, pH)
- Nutrient and contaminant levels (Cadmium, Chromium, Zinc, Phosphate, Nitrate)
- Inorganic constituents (Chloride, Sulphate, Alkalinity, Hardness)
- Physical properties (Colour, Turbidity) [18]. Post 24-hour incubation at room temperature, growth of two distinct bacterial colonies was observed. These colonies were then sub cultured on agar - agar nutrient plates.

Optimization of Growth Media

Overnight-grown inoculums of the two bacterial strains were cultured on various nutrient media.

- Media preparations included different carbon and nitrogen sources (Table 1).
- Additional supplements included bee's extract, NaCl, and agar agar powder.

- Cultures were incubated for 48 hours.
- Both chromate-reducing species (CRS) exhibited growth on diverse nutrient agar plates.
- Optimal growth media conditions were determined using the colony count method (Table 2). The bacterial strains were cultured in nutrient broth for 48 hours to obtain adequate biomass for further analysis. The broth cultures were then centrifuged at 200 rpm for 30 minutes to obtain a pellet of strains.

Table 1: Glucose and Nitrogen sources

S. N	Glucose Source	Nitrogen Source
1	Glucose (G)	Peptone (P)
2	Sucrose (Su)	Peptone (P)
3	Starch (S)	Peptone (P)
4	Glucose (G)	NH ₄ Cl (N)
5	Sucrose (Su)	NH ₄ Cl (N)
6	Starch (S)	NH ₄ Cl (N)
7	Glucose (S)	Urea (U)
8	Sucrose (Su)	Urea (U)
9	Starch (S)	Urea (U)

Table 2: Growth media optimization by colony count method

S N	CFU for SeLB4	CFU for C31171	Growth Media
1	22x10 ⁶	10.8x10 ⁷	AA - P- G- B-NC
2	16x10 ⁶	3X10 ⁷	AA - P -Su -B -NC
3	13x10 ⁶	11.5x10 ⁷	AA - P- S-B- NC
4	7x10 ⁶	00	AA - N- G- B -NC
5	4x10 ⁶	00	AA- N - Su- B- NC
6	2x10 ⁶	00	AA - N S- B- NC
7	9x10 ⁶	00	AA - U- G -B -NC
8	2x10 ⁶	00	AA - U -Su -B -NC
9	7x10 ⁶	00	AA - U- S- B- NC

Encapsulation of CRS-Cell

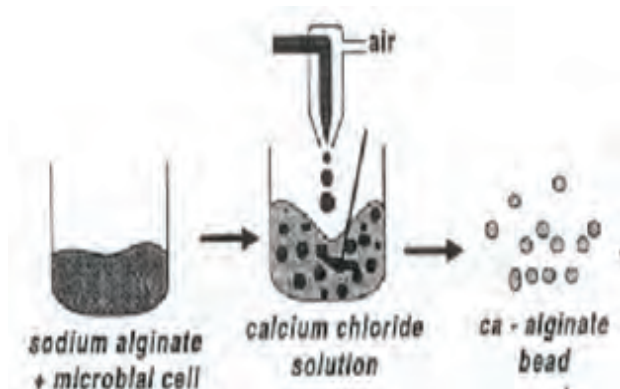
Broth samples having turbidity due to the high concentration of microorganisms were subjected to centrifugation up to 2 hours at 200 revolutions per minute (rpm) to obtain microbial pellets.

Separately, 2.5 grams of sodium alginate was dissolved in 100 millilitres (ml) of water in two flasks, followed by uniform stirring to create homogeneous sodium alginate solutions.

Two flasks were labelled as follows:

1. F-1
2. F-2.

SeLB4 pellet was added to F-1, while the C31171 pellet was added to F-2. To encapsulate the microbes, the mixtures were added drop wise to individual conical flasks containing calcium chloride solution, resulting in the formation of microbial beads. The beads were stored in a calcium chloride solution (1%) in two different flasks.



Separation and Encapsulation of CRS-Enzyme

As microorganisms grew, they released extracellular enzymes into the broth. Following microbial separation, the enzymes were concentrated and purified using ammonium sulphate precipitation. Enzyme Encapsulation Process:

1. Precipitated enzyme was dissolved in a suitable buffer.
2. Enzyme encapsulation was performed using sodium alginate and CaCl_2 .
3. The resulting beads were stored in flasks labelled F-3 and F-4, each containing 1% CaCl_2 .

Preparation of stock solution

Samples of effluent were collected from chosen plating industries, diluted to achieve a $\text{Cr}(6)$ concentration of 100 mg/L. 100 mL of the stock solution was divided equally into two 250 mL conical flasks (50 mL in each), supplemented with 50 g of beads.

Optimization of parameters

To achieve efficient bioreduction of $\text{Cr}(6)$, key parameters such as effluent pH and initial concentration were optimized [19, 20].

$\text{Cr}(6)$ reduction in effluent samples was investigated across a pH range from acidic to basic, achieved by adding 1N NaOH. To optimize initial $\text{Cr}(6)$ concentration, reduction studies were conducted on effluent samples with varying concentrations (25, 50, 75, and 100 ppm), prepared by dilution with distilled water.

RESULT AND DISCUSSION

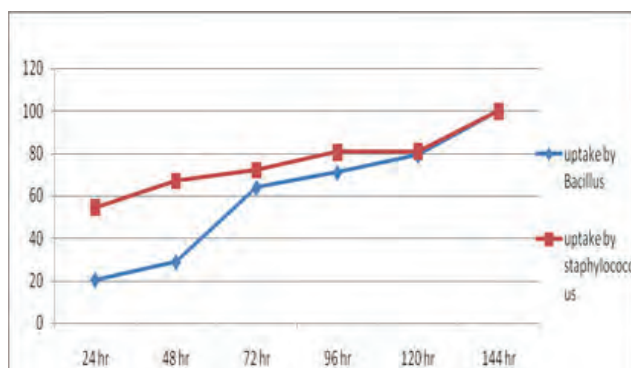
Evaluation of Bioreduction $\text{Cr}(6)$

using Encapsulation Microbes cells: The efficiency of $\text{Cr}(6)$ reduction by encapsulated SeLB4 and C31171 encapsulated cells was evaluated under various conditions, including different time intervals, pH levels, and concentrations.

Contact Duration Effects

- 50g of encapsulated microbial cells were introduced into a flask containing $\text{Cr}(6)$.
- The mixture was subjected to bioreduction $\text{Cr}(6)$ reduction was monitored every 24 hours using UV-Visible Spectrophotometry ($\lambda_{\text{max}} = 540 \text{ nm}$), revealing 100% reduction by Staphylococcus SeLB4

and C31171 within 144 hours as shown in following graph.



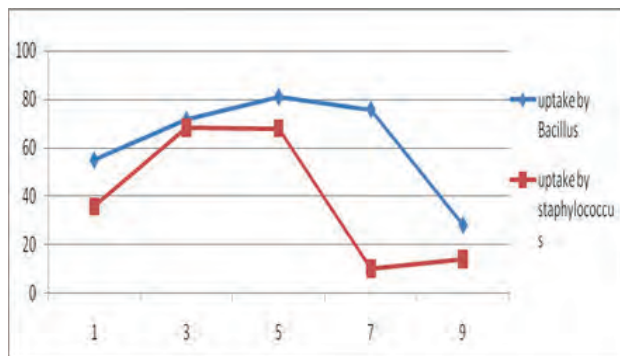
Graph 1 : Time-Dependent Reduction of Toxic Cr(6) 1. Bacillus megaterium cells 2. Staphylococcus sp. cells [% Reduction of Cr(6) vs. time]

Effect of pH

The effluent pH was adjusted from acidic to basic by adding 1N NaOH drop wise.

Chromate-reducing strains (CRS) were added to the adjusted effluent.

Biodegradation of Cr(6) was allowed to occur at various pH levels for 96 hours., revealing maximum bioreduction at pH 5 for both microbial species. as shown in following graph.

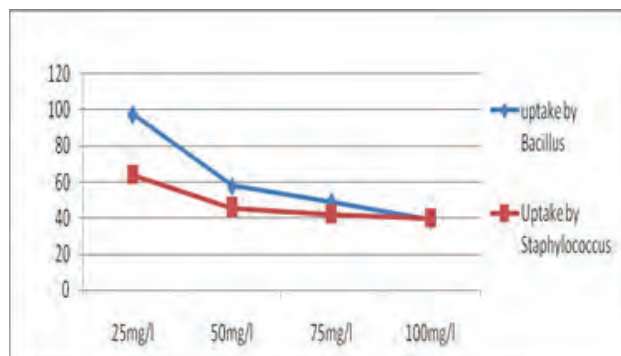


Graph2: pH-Dependent Bioreduction of Cr(6) by Microorganisms 1. Bacillus megaterium cells 2. Staphylococcus sp. cells [% Reduction of Cr(6) vs. pH]

Impact of Changing Cr(6) concentrations in Effluent on Bioreduction Efficiency (using Microbes cells)

Baseline concentration Cr(6) optimization was achieved by analyzing reduction rates in effluent samples with varying Cr(6) concentrations (25-100 ppm), prepared through dilution with distilled water.

It was observed that encapsulated microbial cells of both organisms exhibited increased Cr(6) uptake with decreasing concentration, achieved through dilution of effluent samples. as shown is graph 3.



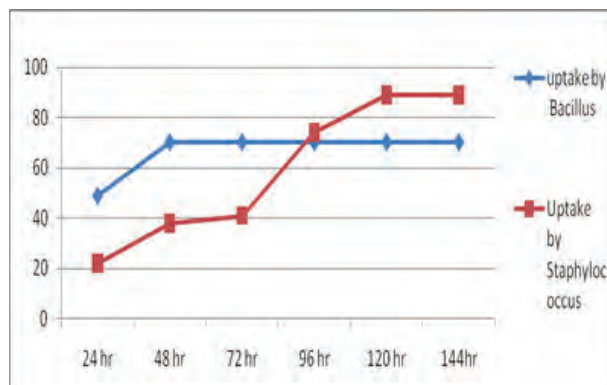
Graph 3 : Concentration -Dependent Bioreduction of Cr(6) by Microorganisms 1. Bacillus megaterium cells 2. Staphylococcus sp. cells [% Reduction of Cr(6) vs. Conc.]

Evaluation of Bioreduction Cr(6) using Encapsulation Microbes Enzyme

Encapsulated enzymes from both isolated Chromium reduction strains (SeLB4 and C31171) effectively reduced Cr(6) from solution. The bioreduction process was assessed based on the following parameters, 1.Time 2. PH 3.Concentration.

Effect of Contact Time

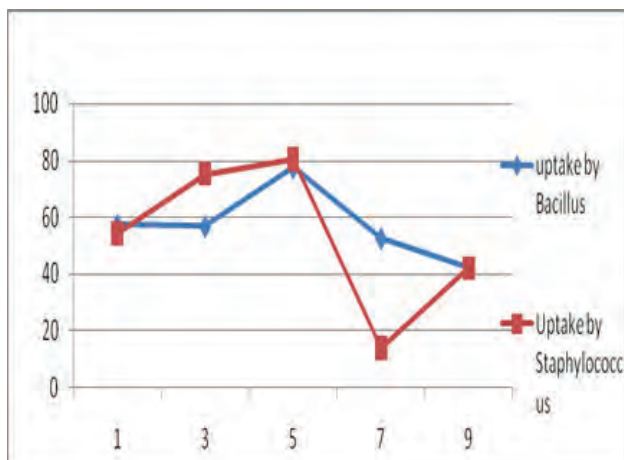
Enzyme-encapsulated beads were applied to a Cr(6) solution to investigate bioreduction. Both SeLB4 and C31171 CRS strains facilitated Cr(6) biodegradation, with uptake monitored every 24 hours, resulting in 70% removal within 96 hours. as shown in graph 4.



Graph 4: Time-Dependent Reduction of Toxic Cr(6) 1. Bacillus megaterium enzymes 2. Staphylococcus sp. enzymes [% Reduction of Cr(6) vs. time]

pH Effect

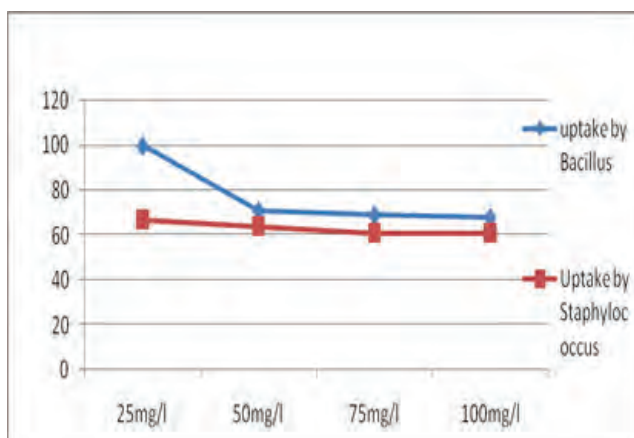
To evaluate the pH effect on biodegradation, the effluent pH was adjusted from acidic to basic. After the period of 96 hours, it was found that pH 7 was optimal for Cr(6) bio reduction by both the microorganisms using enzyme encapsulated beads as shown in graph 5.



Graph 5: pH-Dependent Bioreduction of Cr(6) by Microorganisms 1. Bacillus megaterium enzymes 2. Staphylococcus sp. enzymes [% Reduction of Cr(6) vs. pH]

Impact of Changing Cr(6) concentrations in Effluent on Bioreduction Efficiency (using Microbes Enzymes)

Bioreduction rate of Cr(6) decreased initially with concentration, but then stabilized, using Microbes Enzymes for both microorganisms as shown in graph 6



Graph 6: Concentration -Dependent Bioreduction of Cr(6) by Microorganisms 1. Bacillus megaterium enzyme 2. Staphylococcus sp enzymes [% Reduction of Cr(6) vs. Conc.]

CONCLUSION

Existing technologies for heavy metal cleanup are costly and inefficient. In contrast, microbial-based reduction of Cr(6) can achieve 100% removal within a week, with optimal results (70% reduction) observed at pH 5 and 25% dilution within 96 hours.

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Growth and Characterizations of Nanostructure $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ Thin Films

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ABSTRACT

Thermal evaporation method was used to deposit $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films on top of the glass substrates. A scanning electron microscope was used to analyze the microstructure and assess the phase purity. Deposited thin films showed a monoclinic crystal structure with polycrystalline in nature. The optical transmittance spectra of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films was analyzed and showing the fundamental band gap of 2.2 eV.

KEYWORDS : XRD, SEM, EDAX, UV-VIS Spectroscopy.

INTRODUCTION

CuInSe_2 , a ternary compound, is known for being useful in PV devices because of the higher absorbing coefficient. [1, 2]. For thin-film solar cells, CuInSe_2 has been identified as a promising absorber material. [3]. Crystallinity and compositional balance should be essential factors for these devices for working optimally. Several deposition methods have been used to produce CuInSe_2 thin films, including: Epitaxy of molecular beams [5, 6] used as a pulse laser for thin-film deposition [7] used as a spray pyrolysis for thin-film deposition [8] used as a CBD RF sputtering for thin-film deposition [9] used as a CBD for thin-film deposition [10]. Thermal evaporation is a key method for depositing compound materials due to its informality and reproducibility. CuInSe_2 thin films were deposited using this method by feeding source material onto a molybdenum boat and repeating the evaporation process to achieve the desired thickness. Despite these precautions, other preparative parameters, such as source to substrate distance, deposition rate, and substrate temperature, also plays a significant role. These growth

parameters can lead to variations in structural, optical, and electrical properties. Therefore, it is necessary to study these properties and optimized it for favorable deposition of the film. The present study focus on preparation of optimized CuInSe_2 thin film, which was analyzed by XRD and SEM. Also, studied optical properties such as photo sensing, absorbance spectra, transmission spectra and energy band gap.

LITERATURE REVIEW

CuInSe_2 (CIS), a ternary semiconductor, has become a key material in large-scale thin-film solar cells thanks to its impressive optical and thermal properties. It is one of the most promising candidates for second-generation solar cells, with efficiencies beyond 19%. Polycrystalline nature structural characterization was carried out by XRD and SEM studies these studies confirm the polycrystalline nature CuInSe_2 thin films were deposited on glass substrate from single source thermal evaporation method. Energy band gap was between 1.02 eV to 1.04eV and high absorption coefficient values 1 to $2 \times 10^5 \text{ cm}^{-1}$.

METHODOLOGY

The melt quench process was used to create ternary alloy $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$. The pure mixture of copper, indium and selenium was placed in evacuated quartz tube and heated to approximately 1000°C for 24 hours before it was quenched in ice-cooled water. $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ films were created through thermal evaporation under a pressure of 10^{-5} torr the distance between source and substrate was maintained at 14cm.

The sample with varying thickness were deposited under similar condition. The thickness of the film was assessed using the Digital Thickness Monitor (DTM-101) using by Hind-Hi Vac. The rate of deposition was maintained at 8-10 Å/sec for all sample preparations. Prior to the evaporation process, the glass substrates were meticulously cleaned with chromic acid, detergent, and acetone.

RESULTS AND DISCUSSION

XRD Analysis

The XRD technique is used to study crystalline properties such as crystal structure, size, and nature. $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ samples were scanned at 2θ angles ranging from 0° to 80° . Figure 1 displays the XRD pattern of a thin film of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ with a thickness of 500 Å.

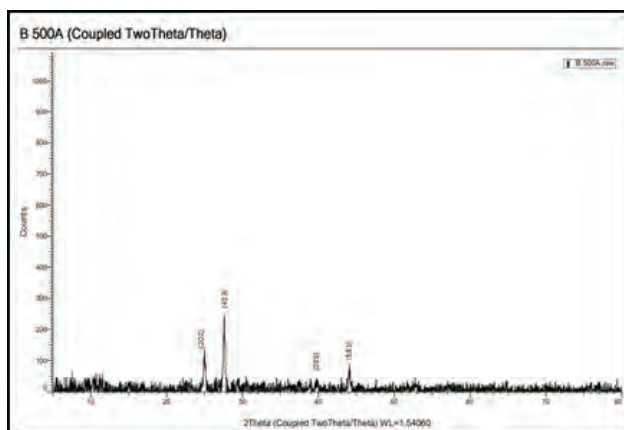


Fig. 1: XRD Spectrum of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ Thin Film

The hkl plans (202), (423), (035), and (551) show 2θ peaks at 24.992° , 27.588° , 39.827° , and 44.060° , respectively. The desires for reflection are in good agreement with the JCPDS data. The XRD pattern contains many peaks. It indicates the material's polycrystalline nature. [7-11]. The primary peak is of monoclinic shape. The average crystalline size (D) was calculated using the Scherrer equation.: where λ is the wavelength of X-ray, β is Full

Width Half Maxima, and θ is the diffraction angle. The crystal size was found to be 3692 nm.

SEM Analysis

Analysis using FE Scanning Electron Microscope (SEM) can be used to study the surface morphology. FESEM (Zeiss EVO50) was used to assist with the SEM study. The SEM pictures of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films are displayed in Figure 2. It is evident from the SEM pictures that the film was uniform. The granules are evenly dispersed over the substrate's surface. The nanoparticles are stacked closely together [13]. Clusters are formed by the nanograins. It is discovered that the clusters have spherical forms. For both samples, the average cluster size is approximately 13 nm. There are no minute flaws in the samples, such as peeling or cracking. The films surfaces were adequately flat.

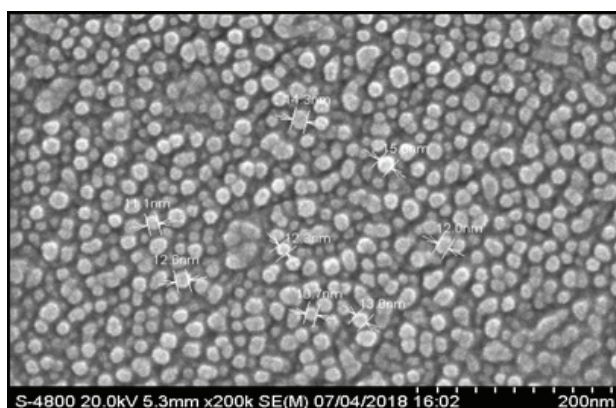


Fig. 2: SEM Image of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ Thin Film

Elemental Analysis of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ Thin Films

The quantitative elemental analysis of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films were done by EDAX. The EDAX spectrum of the $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin film is shown in Fig.3 for thickness 500 Å. The present elements were detected at 0.19, 9.1 and 10.30 KeV with atomic percentages of 1.46%, 55.44 and 43.10%. There is no evidence found of any type of impurities. It proves the purity of grown sample. The presences of other peaks are due to the glass substrate and gold coating during the characterizations.

UV – VIS Spectroscopy

The optical properties like absorbance transmittance of grown $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin film were studied by using UV – VIS Spectroscopy. The optical absorption patterns were obtained within the 400 – 800 nm wavelength ranges by using UV – VIS Spectrophotometer. Absorbance and transmittance spectra of grown $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films are

plotted in figures 4 and 5 respectively. Higher absorbance is noticed within the 425-475 nm wavelength regions. The $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films with various thicknesses have good absorbance. Hence the it can be used as absorber material in fabrication of solar cell.

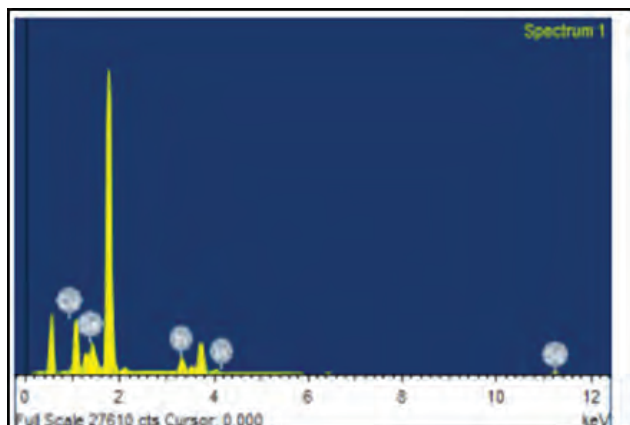


Fig. 3: EDAX Pattern of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ Thin Film

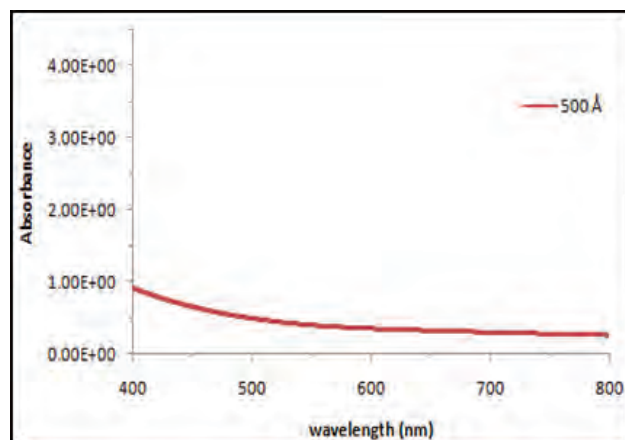


Fig. 4: Absorbance pattern

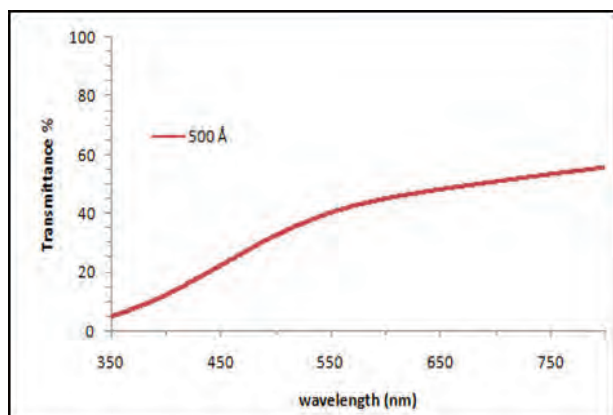


Fig. 5: Transmittance pattern

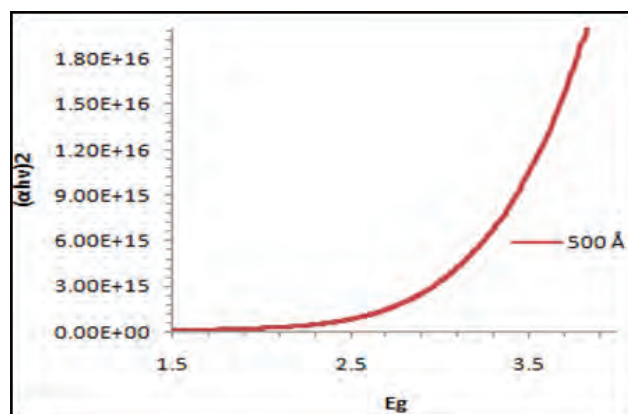


Fig. 6: Band Gap Pattern

The relation (Tauc 1974) has been used to compute the optical band gap (E_g) of the samples with the help of α and $h\nu$, the absorption coefficient and the photon energy respectively. The developed $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films' optical band gap was calculated using a plot of $(\alpha h\nu)^2$ Vs E_g and Fig. 6 displays the band gap pattern. The material $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ has a direct band gap. Figure 6 shows that the optical band gap of the $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin films that were produced had a thickness of 500 Å and was approximately 2.2 eV.

Photo sensing

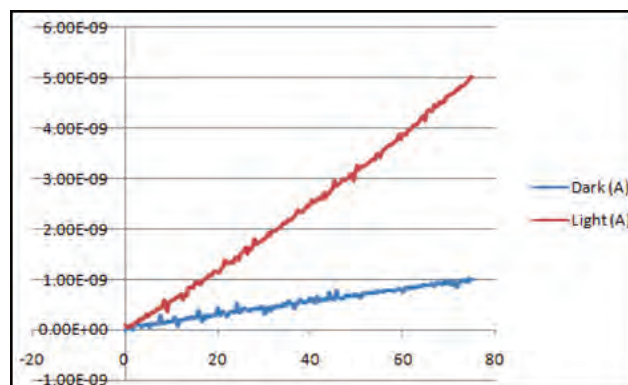


Fig. 7: I-V Plot of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ Thin Film

The I-V plot of $\text{Cu}_{0.5}\text{In}_{0.5}\text{Se}$ thin film for 500 Å thicknesses recorded in both dark and bright conditions is displayed in Fig. 7. The I-V pattern shows that in both dark and bright situations, current increases in relation to voltage. Additionally, compared to the current measured in dark conditions, the recorded current in the presence of light was comparatively higher. When exposed to light, photosensitive materials often exhibit an increase in photocurrent. Using light current and dark current, the

photosensitivity of grown Cu_{0.5}In_{0.5}Se thin films was determined to be 3.20 as follows:

$$S = \frac{I_l - I_d}{I_d}$$

CONCLUSIONS

The XRD study reveals the polycrystalline nature of Cu_{0.5}In_{0.5}Se thin film having monoclinic crystal structure. The SEM reveals that grains are spherical in shape and uniform distribution over the substrate. Presence of required constituent elements and stoichiometry was confirmed using EDAX analysis. Further band gap of the material was calculated to be 2.2eV. Hence, the material is very suitable for manufacturing efficient photovoltaic devices. Photosensitivity of grown Cu_{0.5}In_{0.5}Se thin films was determined to be 3.20.

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Analysis of Nonlocal Thermoelasticity Effects Using Transformation Methods by Applying Boundary Conditions

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ABSTRACT

This is review based paper which contains analysis of nonlocal thermo elasticity effects using different mathematical transformation methods by applying different boundary conditions. It examines the effects of nonlocal thermo elasticity by employing transformation methods to solve coupled thermal and mechanical field problems under specified boundary conditions. Nonlocal thermo elasticity extends classical theories by incorporating long-range interactions and microstructural effects, which are crucial for analyzing nano scale materials and complex heterogeneous structures. Transformation techniques, such as Laplace and Fourier transforms are applied to derive analytical solutions to the governing equations, which consider nonlocal elasticity, heat conduction and thermal stress. The study investigates the interactions between displacement, stress, and temperature fields under various boundary conditions, including prescribed displacements, thermal gradients and surface stresses. The use of transformation methods facilitates solving integral-differential equations in nonlocal theories, enabling the exploration of size-dependent and boundary induced phenomena. The results reveal the critical influence of nonlocal parameters on stress and temperature distributions, particularly in small-scale systems and near boundaries. This work enhances the understanding of nonlocal thermo elastic effects, providing insights into the design and optimization of advanced materials and devices where nonlocal interactions and thermal coupling play a crucial role.

KEYWORDS : *Boundary conditions, Internal moving heat source, Integral transform techniques, Nonlocal thermoelasticity & Thermal stress.*

INTRODUCTION

Nonlocal thermoelasticity has emerged as a pivotal field in mechanics, addressing the limitations of classical theories by incorporating the effects of long-range interactions and microstructural dependencies. These nonlocal effects are particularly prominent in materials and structures at small scales, such as nanoscale systems and heterogeneous composites, where classical thermoelasticity fails to capture size-dependent behaviors accurately [9].

The coupling between thermal and mechanical fields in nonlocal thermoelasticity introduces significant complexities, as the stress, strain, and temperature fields are influenced not only by local conditions but also by interactions over finite distances.

Analytical solutions to these problems often involve integral-differential equations, which are challenging to solve directly. Transformation methods, such as Laplace and Fourier transforms, provide a robust framework for addressing these challenges by converting the governing equations into more manageable forms [2].

This study focuses on analyzing the effects of nonlocal thermoelasticity under various boundary conditions, emphasizing the role of nonlocal parameters in influencing thermal and mechanical responses. By employing transformation techniques, the study explores size-dependent phenomena and boundary-induced effects, providing critical insights for the design and optimization of advanced materials and devices where nonlocal interactions significantly impact performance [4].

ANALYSIS PARAMETERS

Nonlocal Thermoelasticity Effects

Nonlocal thermoelasticity refers to the study of the interplay between thermal and elastic fields in materials where the mechanical and thermal responses exhibit spatial nonlocal effects. This theory extends classical thermoelasticity by considering the effects of interactions at distances beyond the immediate vicinity of a material point, thereby accounting for microscale or nanoscale phenomena [9].

Nonlocal thermoelasticity is a theory that considers how physical quantities depend on the values of a system's variables, not just the values at a single point. It can be used to predict the thermoelastic response of nanostructures, which is important for their design and processing.

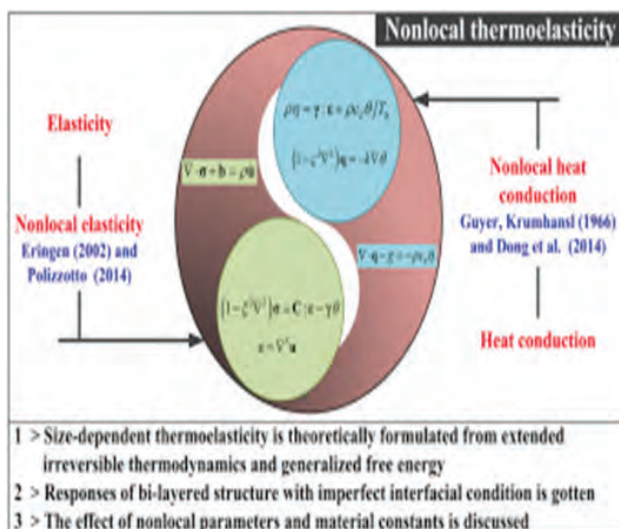


Fig. 1 Nonlocal Thermoelasticity [9]

List of Nonlocal Thermoelasticity Effects:

1. Size-Dependent Behavior: Material properties and responses vary with scale, especially in nanoscale systems.

2. Long-Range Interactions: Nonlocal effects account for atomic and microstructural influences beyond nearest neighbors.
3. Modified Stress Distribution: Stress fields differ from classical predictions, particularly near boundaries.
4. Thermal Softening: Increased influence of thermal effects on mechanical properties due to nonlocal interactions.
5. Enhanced Wave Dispersion: Nonlocality alters wave propagation characteristics in thermoelastic media.
6. Boundary-Induced Phenomena: Significant stress and temperature variations near constrained surfaces.
7. Coupled Displacement-Temperature Fields: Stronger interdependence between thermal and mechanical responses.
8. Reduction in Effective Stiffness: Nonlocal interactions lead to apparent softening of materials.
9. Altered Heat Conduction Mechanisms: Deviations from Fourier's law in nanoscale heat transfer.
10. Impact on Material Stability: Nonlocal effects influence buckling and failure mechanisms.
11. Temperature-Dependent Nonlocal Effects: Nonlocal parameters may vary with temperature gradients.
12. Modified Thermal Stresses: Redistribution of thermal stress fields due to nonlocal contributions.
13. Influence on Fracture and Damage Mechanics: Nonlocality affects crack propagation and defect evolution.
14. Application-Specific Anomalies: Unique behaviors in composites, thin films, and biomaterials.

Transformation Methods

Transformation methods in the context of mathematical physics, engineering or applied sciences refer to techniques that convert complex equations or problems into simpler forms that are more solvable. These methods are widely used in fields such as heat transfer, elasticity, fluid mechanics and quantum mechanics [2].

Below is an overview of key transformation methods and their applications:

Table 1 Transformation Methods [7]

Transformation Methods	Description	Applications
Laplace Transform	Used to convert differential equations in the time domain into algebraic equations in the Laplace (frequency) domain.	1) Solving ordinary and partial differential equations (ODEs and PDEs) with initial conditions. 2) Analyzing systems in control engineering and signal processing. 3) Modeling heat conduction and wave propagation.
Fourier Transform	It decomposes functions into their constituent frequencies, useful for periodic and non-periodic signals	1) Solving PDEs in infinite or semi-infinite domains (e.g., heat and wave equations). 2) Signal and image processing. 3) Quantum mechanics (e.g., wave functions).
Z-Transform	Used for discrete-time signals and systems, converting sequences into complex frequency domain representations.	1) Digital signal processing (DSP). 2) Control systems for discrete-time models.
Conformal Transform	It map one complex domain into another while preserving angles. They simplify solving problems in fluid dynamics and electrostatics.	1) Aerodynamics (e.g., airfoil design using Joukowski transform). 2) Electrostatics and heat conduction in complex geometries.
Wavelet Transform	Wavelet transforms decompose signals into components with localized time and frequency characteristics, useful for non-stationary data.	1) Image and signal compression. 2) Solving PDEs with time-varying or localized features. 3) Fault detection in systems.

Integral Transform	It generalize methods like Laplace and Fourier by mapping a function into another domain through kernel functions.	1) Solving boundary value problems. 2) Analysis of linear systems.
Coordinate Transformations	These involve changing the coordinate system to simplify equations or boundaries, commonly used in PDEs.	1) Fluid dynamics (e.g., Navier-Stokes equations in curved geometries). 2) Thermoelasticity and stress analysis in curved bodies.
Similarity Transformations	It reduce the number of independent variables in a PDE, turning it into an ODE under specific conditions.	1) Boundary layer theory. 2) Heat and mass transfer problems.
Nonlocal Transformations	Used in systems governed by nonlocal effects, these methods account for integral kernels or fractional derivatives.	1) Nonlocal elasticity and thermoelasticity. 2) Fractional-order systems in physics and biology.

Boundary Conditions

Boundary conditions are constraints that define the values of a variable at the boundary of a domain. They are used in many fields, including finance, fluid dynamics, and computational fluid dynamics [1].

Boundary conditions (BCs) are constraints applied to the boundaries of a domain in mathematical and physical problems. They are essential for solving differential equations (ODEs or PDEs) and determining a unique solution for physical systems. Boundary conditions depend on the nature of the problem and the type of equation being solved.

Importance of Boundary Conditions

- 1) Ensures well-posedness of mathematical models (existence, uniqueness, and stability of solutions).
- 2) Reflects physical realities (e.g., insulation, thermal contact, structural support) [4].
- 3) Determines the behaviour of solutions (e.g., steady-state, transient or oscillatory) [5].

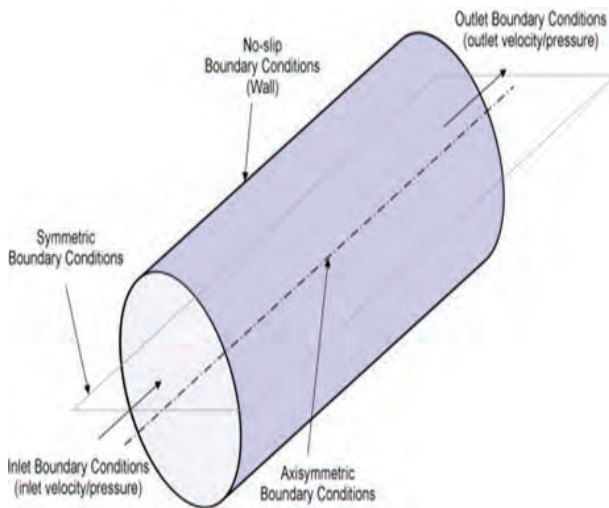


Fig. 2 Boundary Conditions [9]

Techniques for Applying Boundary Conditions:

- 1) Analytical Methods: Solving the governing equations with BCs using methods like separation of variables or integral transforms [6].
- 2) Numerical Methods: Discretizing the equations (e.g., finite difference, finite element) and incorporating BCs into the numerical scheme.

Below is an overview of types and examples of boundary conditions [3].

Table. 2 Types of Boundary Conditions

Types of Boundary Conditions	Description
Dirichlet Boundary Condition (Essential BC)	Specifies the value of the function at the boundary.
Neumann Boundary Condition (Natural BC)	Specifies the value of the derivative of the function (normal flux) at the boundary.
Robin Boundary Condition (Mixed BC)	A combination of Dirichlet and Neumann conditions.
Periodic Boundary Condition	Specifies that the function and its derivatives are the same at the boundary's endpoints.
Mixed Boundary Conditions	Different types of BCs are applied on different parts of the boundary.
Cauchy Boundary Condition	Specifies both the function and its derivative on the boundary.

Internal moving heat source

An “internal moving heat source” refers to a heat source that generates heat within a material or system and is not stationary, meaning it changes its location over time, effectively “moving” through the material as it produces heat; this can be seen in applications like a moving laser beam heating a metal piece, or the heat generated by a moving component inside a machine [8].

An internal moving heat source refers to a scenario where a localized heat source moves through a medium, depositing heat along its path. This phenomenon is common in applications like welding, laser cutting, frictional heating and biological tissue heating during laser surgeries.

The analysis of this problem involves solving the heat conduction equation with terms that account for the moving heat source [10].

CONCLUSIONS

The study underscores the critical role of nonlocal parameters in governing thermal and mechanical responses in small-scale and heterogeneous systems. By employing transformation methods, it highlights size-dependent and boundary-induced effects, offering valuable insights for optimizing advanced materials and devices influenced by nonlocal interactions and thermal-mechanical coupling.

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Benchmarking and Performance Metrics for Academic Libraries

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ABSTRACT

Academic libraries play a crucial role in supporting higher education institutions by providing access to scholarly resources, research support, and learning services. Evaluating their performance is essential for ensuring continuous improvement and effective resource utilization. This research explores benchmarking and performance metrics in academic libraries, highlighting key frameworks, methodologies, and challenges. The study also examines best practices and case studies to provide a comprehensive understanding of how benchmarking contributes to the enhancement of library services.

KEYWORDS : *Benchmarking, Performance metrics, Academic libraries, Library assessment, Key performance indicators (KPIs), User satisfaction, Service quality, Data-driven decision making, Resource utilization, Comparative analysis.*

INTRODUCTION

Academic libraries are dynamic entities that must adapt to changing educational landscapes, technological advancements, and user needs. Performance measurement through benchmarking enables libraries to assess their effectiveness, compare with peer institutions, and identify areas for improvement. Various metrics, such as service quality, collection usage, and digital resource accessibility, provide a quantitative basis for evaluation. This paper discusses the importance of benchmarking, commonly used performance indicators, and best practices in the field.

DEFINITION

Benchmarking and performance metrics for academic libraries involve the systematic measurement and comparison of library services, operations, and resources against established standards, best practices, or peer institutions. These processes help academic libraries assess their effectiveness, identify areas for improvement, and enhance overall service quality.

AIMS

1. Enhance Service Quality – Improve the efficiency and effectiveness of library services by identifying best practices.

2. Support Strategic Planning – Provide data-driven insights for decision-making and resource allocation.
3. Ensure Accountability – Demonstrate value and impact to stakeholders, including university administration, students, and faculty.
4. Facilitate Continuous Improvement – Identify strengths and weaknesses to refine policies, procedures, and services.
5. Promote User Satisfaction – Align library offerings with the needs and expectations of students and researchers.

OBJECTIVES

1. Measure Library Performance – Establish key performance indicators (KPIs) such as circulation statistics, database usage, and user satisfaction.
2. Compare with Peers – Benchmark services against similar institutions to identify best practices and performance gaps.
3. Optimize Resource Utilization – Evaluate the effectiveness of library expenditures, staffing, and collection management.
4. Improve Decision-Making – Use data analytics to

support evidence-based improvements and policy development.

5. Enhance Digital Services – Assess the impact of online resources, digital repositories, and library technology.
6. Foster Institutional Collaboration – Participate in consortiums and benchmarking initiatives to share insights and strategies.

By implementing benchmarking and performance metrics, academic libraries can enhance their role as essential knowledge hubs, ensuring they continue to meet the evolving needs of students, faculty, and researchers.

BENCHMARKING AND PERFORMANCE METRICS FOR ACADEMIC LIBRARIES

Main Content

Academic libraries serve as critical hubs for research, learning, and knowledge dissemination within educational institutions. To maintain relevance and continuously improve services, these libraries leverage benchmarking and performance metrics to assess their effectiveness. By comparing key performance indicators (KPIs) against peer institutions and established standards, academic libraries can identify strengths, uncover areas for improvement, and enhance user satisfaction.

Importance of Benchmarking in Academic Libraries:

Benchmarking involves comparing an institution's performance with similar organizations to identify best practices and set achievable goals. In academic libraries, benchmarking helps in:

- Resource Allocation: Understanding how budget and resources are distributed compared to peer libraries.
- Service Quality: Measuring user satisfaction and accessibility of services.
- Collection Development: Evaluating the breadth and depth of collections relative to other institutions.
- Technological Integration: Assessing the effectiveness of digital services and technology adoption.

Key Performance Metrics

Performance metrics provide quantitative data that reflect the efficiency and impact of library services. Common metrics include:

- Circulation Statistics: Number of books and materials borrowed over a period.
- Gate Count: The frequency of user visits to the library.
- Electronic Resource Usage: Downloads and access statistics for digital databases and journals.
- Information Literacy Sessions: Number and attendance of workshops aimed at enhancing research skills.
- User Satisfaction Surveys: Feedback on services, resources, and overall user experience.

Methods of Benchmarking

- Internal Benchmarking: Comparing performance over time within the same institution to track progress.
- External Benchmarking: Evaluating performance against peer institutions or industry standards.
- Best Practice Benchmarking: Learning from exemplary libraries known for superior performance.

Challenges in Benchmarking and Metrics

While benchmarking offers valuable insights, academic libraries face challenges such as:

- Data Collection and Accuracy: Ensuring reliable and consistent data across all metrics.
- Contextual Differences: Variability in institutional size, funding, and user demographics.
- Evolving Standards: Keeping up with technological advancements and changing user expectations.

Impact on Strategic Planning

Benchmarking and performance metrics inform strategic planning by:

- Highlighting priorities for funding and resource allocation.
- Driving policy changes to improve user satisfaction.
- Encouraging innovation in service delivery.
- Demonstrating accountability to stakeholders and funding bodies.

Benchmarking in Academic Libraries

Benchmarking is a systematic process of comparing services, processes, and performance metrics of one

library against others, often with the goal of adopting best practices. It involves several steps:

1. Identifying Peer Institutions – Selecting comparable libraries based on size, funding, research focus, or user demographics.
2. Defining Performance Metrics – Establishing key indicators such as circulation statistics, electronic resource usage, and reference transactions.
3. Data Collection and Analysis – Gathering quantitative and qualitative data through surveys, internal records, and external sources.
4. Comparison and Interpretation – Analysing collected data to identify strengths and weaknesses.
5. Implementation of Improvements – Applying findings to enhance services and optimize library operations.

Key Performance Metrics

Academic libraries employ various performance indicators to assess their effectiveness. Some of the widely used metrics include:

- Input Metrics
 - o Library budget and expenditures
 - o Number of staff and qualifications
 - o Collection size (print and electronic resources)
- Output Metrics
 - o Circulation statistics
 - o Interlibrary loan transactions
 - o Number of reference inquiries
- Usage Metrics
 - o Digital resource downloads
 - o Gate count and visitor statistics
 - o Database search sessions
- Impact Metrics
 - o User satisfaction surveys
 - o Research output facilitated by library resources
 - o Contribution to institutional academic rankings

Benchmarking Frameworks

Several frameworks guide the benchmarking process in academic libraries. Some prominent ones include:

- LIBQUAL+: A widely used survey-based framework assessing user perceptions of library service quality.
- ARL (Association of Research Libraries) Statistics: Provides standardized data for comparing large research libraries.
- Sconul (Society of College, National, and University Libraries) Statistics: Common in the UK, offering insights into operational efficiency and service quality.
- ISO 11620 Library Performance Indicators: An international standard defining key performance measures.

Challenges in Benchmarking

Despite its advantages, benchmarking academic libraries faces several challenges:

- Data Collection Issues: Variability in data collection methods across institutions can lead to inconsistencies.
- Resource Constraints: Conducting comprehensive benchmarking studies requires time and financial resources.
- Rapid Technological Changes: Metrics need continuous updates to reflect emerging trends such as open access and digital repositories.
- Institutional Differences: Differences in academic focus, student demographics, and funding models make direct comparisons difficult.

Best Practices for Effective Benchmarking

To maximize the benefits of benchmarking, libraries should:

- Establish clear objectives for performance measurement.
- Use a combination of quantitative and qualitative metrics.
- Collaborate with consortia and benchmarking networks.
- Continuously review and refine benchmarking strategies based on evolving user needs.

Case Studies

1. The University of Michigan Library adopted LIBQUAL+ surveys to measure service quality, leading to improved user engagement strategies.

2. The British Library utilized ISO 11620 indicators to refine its digital resource management, enhancing accessibility.
3. Harvard University Library leveraged ARL statistics to optimize its collection development policies, ensuring balanced resource allocation.

Examples of Benchmarking and Performance Metrics for Academic Libraries

Benchmarking and performance metrics for academic libraries help evaluate their effectiveness, efficiency, and overall impact on students, faculty, and research outcomes. Here are some key examples:

Service Quality Metrics (LibQUAL+)

- Definition: A standardized survey tool used to measure user perceptions of service quality.
- Metrics:
 - o Library staff helpfulness and competence
 - o Access to resources (both digital and physical)
 - o Library environment and facilities
- Example:
 - o “90% of respondents rated staff helpfulness as ‘excellent’ in the 2024 LibQUAL+ survey.”

Resource Usage Metrics

- Definition: Tracks how often resources are accessed or used.
- Metrics:
 - o Number of book circulations and renewals
 - o E-book and journal article downloads
 - o Database access sessions
- Example:
 - o “Journal article downloads increased by 20% after introducing off-campus access.”

Collection Development Metrics

- Definition: Measures the relevance, adequacy, and diversity of library collections.
- Metrics:
 - o Percentage of budget spent on electronic vs. print resources

- o Average age of the collection (to assess up-to-date materials)
- o Citation impact of library-owned resources in academic publications
- Example:
 - o “80% of newly acquired materials were requested by faculty for research support.”

User Engagement Metrics

- Definition: Assesses how actively students and faculty engage with library services.
- Metrics:
 - o Attendance at library workshops and events
 - o Number of reference questions or consultations
 - o Study room bookings and library foot traffic
- Example:
 - o “Study room bookings increased by 30% during exam periods compared to the previous semester.”

Digital Services Performance

- Definition: Evaluates how well digital platforms and services support users.
- Metrics:
 - o Website traffic and page views
 - o Time spent on digital platforms
 - o Mobile app downloads and usage statistics
- Example:
 - o “The library website received 100,000 page views during the first week of the semester.”

Student and Faculty Satisfaction Surveys

- Definition: Collects feedback on user experiences and satisfaction with library services.
- Metrics:
 - o Net Promoter Score (NPS) – Likelihood to recommend the library
 - o Satisfaction ratings for facilities and services
 - o Feedback on resource accessibility

- Example:
 - o “85% of students reported satisfaction with library study spaces in the annual survey.”

Research Support Metrics

- Definition: Measures how well the library supports research productivity.
- Metrics:
 - o Number of research consultations conducted
 - o Assistance with citation management and data services
 - o Number of publications citing library-supported resources
- Example:
 - o “Faculty publications citing library resources increased by 15% in 2024.”

CONCLUSION

Benchmarking and performance metrics are essential tools for academic libraries to evaluate their effectiveness and drive service improvements. By adopting standardized frameworks and best practices, libraries can enhance

user satisfaction, resource allocation, and operational efficiency. Future research should focus on integrating emerging technologies like artificial intelligence and big data analytics to refine benchmarking processes further.

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