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SANKALCHAND PATEL UNIVERSITY

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FOR A BETTER TOMORROW

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President

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Visnagar 384315, India

Date: 01.07.2025

FOREWORD

Sankalchand Patel University has my gratitude and pleasure to release **the Second Volume, Issue-01** of the University Journal, "**SPU-Journal of Science, Technology, and Management Research**". I take great pride in this journal's services, which particularly benefit students, researchers, and educators in the fields of science, technology, and management. This magazine publishes articles with theoretical frameworks and application scopes that meet the cutting-edge requirements of science, technology, management, fashion design, and commerce fields.

This journal stands as a testament to the relentless pursuit of knowledge, the dedication of our scholars, and the commitment to excellence that defines our institution. The articles within this first volume represent a diverse array of ground-breaking research, innovative ideas, and thought-provoking insights that showcase the intellectual vitality of our academic community. I encourage each member of the community to engage with the contents of this journal, fostering dialogue, collaboration, and further exploration of the ideas presented. The SPU Journal is a platform for the exchange of knowledge and the cultivation of a vibrant scholarly community, and I am eager to witness the impact it will undoubtedly have on our academic landscape.

I commend the editorial team for their meticulous work in bringing together this collection of scholarly works. I feel proud of the journal published by Sankalchand Patel University. I congratulate the Editorial team of the journal "**SPU-Journal of Science, Technology and Management Research**" for making this **Volume-II, Issue-01** successful.

Wish you all the best for your future endeavors.

Shri Prakashbhai Patel
President

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EDITOR'S NOTE

The university is pleased to release the second volume of the journal, **"SPU- Journal of Science, Technology and Management Research (SPU-JSTMR)"** which features research and review papers authored by students, professors and researchers from various Institutions. This journal brings research articles in Interdisciplinary fields and due focus is given to science, technology and management areas. The Sankalchand Patel University Journal of Science, Technology and Management Research (SPU-JSTMR) facilitates the rapid dissemination of original theoretical and applied research findings from a variety of disciplines, including Engineering, Science, Commerce, Management, Computer Applications and Fashion Design.

The papers may contain original research contributions such as state-of-the-art literature reviews, mathematical analyses, mathematical modeling and simulation analyses, design procedures, computer flowcharts and programs, real-world implementation, hardware realization in science and technology, and management case studies in all published articles and research papers in their entirety.

The present volume carries 16 articles written by research scholars and professors of Science, Technology and Management disciplines. We sincerely express our gratefulness to Honourable President Shri Prakashbhai Patel, Honourable Provost, Prof. (Dr.) Prafulkumar Udani for all their support in undertaking the publication of research articles and perfectly completing the task. We sincerely express our thanks to the Honourable Director, Prof. (Dr.) Hetalkumar Shah for unprecedented guidance from inception to the publication of this volume. We thank editorial board members and reviewers for providing fruitful comments for revising and improving the research paper's quality. We thank to scholars and professors for their valuable papers submitted for publication in the journal.

Dr. Rajesh P. Patel

Dr. Hitesh H. Mehta

CONTENTS

Experimental Investigation for Enhancement of CNC Turning Tool for a Different Quenchants

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Abstract: Machining procedures are used in many manufacturing industries. One of the most basic cutting techniques used in metalworking is turning. Surface polish and dimensional tolerance are two important characteristics of a turned product that are used to assess and establish its quality. In this research, experimental work has been investigated in order to increase the quality output of CNC turning operations by the optimization of input parameters. Applications of Heat Treatment techniques are crucial for increasing tool life and improving quality in a variety of industries. The practice of precisely heating and cooling metals to alter their mechanical and physical properties without changing the material's shape. This technique can be used to increase hardness.

Keywords: Turning operation, Heat Treatment Process, Surface Roughness, PXD185941.

I. INTRODUCTION

The machining process that creates cylindrical pieces is called turning. It is the machining of an exterior surface in its most basic form: 1. With the work piece revolving. 2. With a single-point cutting tool, and • With the cutting tool feeding at a distance that will remove the work's outer surface while remaining parallel to the work piece's axis. Turning is done on a lathe that has the power to feed the cutting tool at a certain rate and depth of cut and to turn the work piece at a specific rotating speed. Thus, in a turning operation, three cutting parameters—cutting speed, feed, and depth of cut—need to be established. The performance and wear of the mating parts are significantly influenced by the quality of the mating components whenever two machined surfaces come into contact with one another. Numerous factors, including the following, affect the height, form, arrangement, and direction of these surface flaws on the work piece: A) The machining parameters, such as feed and cutting speed. c) Cut depth. d) Cutting tool wears, and e) A number of additional factors Applying heat treatment procedures to CNC tool inserts can greatly improve their strength and usefulness.

1.1 Increased Hardness: The hardness of the CNC tool insert can be increased by heat treatment techniques including quenching and tempering. The high heat and stresses that are present during machining operations like turning are better tolerated by harder inserts. Longer tool life and less wear are the results of this improved hardness.

1.2 Improved Wear Resistance: The CNC tool insert may develop a harder surface layer as a result of heat treatment procedures like carburizing or nitriding. Longer tool life and improved performance are the results of this hardened layer's exceptional resistance to abrasive wear and frictional pressures experienced during machining processes.

1.3 Enhanced Toughness: Maintaining sufficient toughness is just as important as hardness in order to avoid tool chipping or fracture during milling. The CNC tool insert can attain a balance between toughness and hardness with appropriate heat treatment and tempering, guaranteeing that it can tolerate the impacts and stresses experienced during cutting.

1.4-Dimensional Stability: By reducing internal tensions, heat treatment enhances the dimensional stability of the CNC tool insert. This guarantees that the insert will precisely keep its size and shape

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An easy way to comply with the Journal paper formatting requirements is to use this document as a template and even after extended use, producing accurate and reliable machining results.

1.5 Optimized Microstructure: The CNC tool insert material's microstructure can be precisely controlled through heat treatment. Manufacturers can improve the microstructure to increase mechanical qualities like strength, toughness, and wear resistance by adjusting the heating and cooling processes. This produces a tool insert that is more resilient and long-lasting.

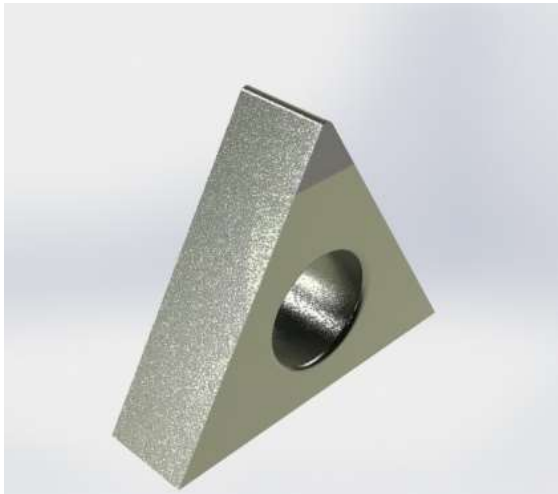

Fig. 1 PXD-18594Z

II. LITERATURE REVIEW

Induction hardening enhanced the microstructure and machining-induced residual stresses of hardened AISI 4340 steels, according to W. Jomaa et al. (2016). Cutting circumstances were observed to have an impact on the distribution of residual stresses; more particularly, a higher cutting speed (202 m/min) causes tensile residual stresses on the surface [01]

AISI 52100 steel hard turning's machinability properties, including surface roughness, tool wear, and chip morphology, were evaluated by A. Panda et al. (2018) using a multilayered coated carbide tool. Researchers noticed a significant improvement in surface roughness quality in the higher feed rate range due to the vibration created during the hard turning process. The high machining temperature generated during dry hard turning at the chip-tool and tool-work piece interfaces affects the surface integrity of AISI 52100 steel. The machining zone's high temperature generation is decreased by efficient cooling and lubrication. Traditional flood cooling has several drawbacks, such as expensive processing costs, pollution from inappropriate disposal, and hazardous odors for workers. [02]

Using a CBN cutting tool, M. Bicek et al. (2012) examined the machinability of hardened and normalized AISI 52100 steel under dry, flood, and cryogenic chilling environments. It has been demonstrated that cryogenic cooling has less micro hardness variation and a thinner white layer than dry and flood cooling. [03]

V. Derflinger and colleagues (1999) investigated the benefits of cooling lubricants in machining operations. But the cost of using, maintaining, and discarding coolant lubricant is substantial. Investigations have shown that using coolant lubrication can sometimes be far more expensive than the tool itself. The deposition of a hard/lubricant coating on cutting tools seems to be a very interesting alternative to remove the large amounts of cooling emulsion in metal cutting and to function with little to no lubrication in a range of applications. Possible uses include alloyed steel machining, cast iron, and aluminum alloys [04].

The machining of AISI-304 steel was assessed by S. Berkania et al. (2015) in terms of surface roughness, specific cutting force, power consumption, and force development. The findings showed that the key factor impacting surface roughness was feed rate. However, the depth of cut has a major effect on cutting power and force, respectively. [05]

In their study of 2013, M. Kaladhar et al. examined how machining parameters affected flank wear, surface roughness, and performance indicators when turning AISI 304 austenitic stainless steel. The results showed that cutting speed influences both surface roughness and tool flank wear. [06]

The RSM approach is used by P. Saini et al. (2014) to determine the ideal machining parameters that result in the least amount of surface roughness during the turning process. [07] A 2009 study by M. Nalbant et al. examined AISI 1030 steel machining without the use of cooling solutions. Research has been done on the effects of feed rate, cutting speed, coating substance, and coating procedure on the work piece's surface roughness. The findings showed that compared to an untreated tool, a coated tool offers better surface roughness values. [08]

The surface roughness results of hardened AISI D2 steel in hard turning using a coated carbide tool were investigated by Sahoo (2014). Because BUE formation vanished and chip-tool contact length shrank, the researcher found that higher cutting rates led to less surface roughness. [09] The method of creating white and black layers during hard machining of AISI 52100 steels was investigated by Zhang et al. (2018). After machining, researchers found that a white coating is produced by a rapid transition in the austenite phase with a quenching effect brought on by the combined action of plastic deformation and phase changes. However, the combined effects of high temperature and plastic deformation on the tempering process resulted in the black layer [10].

III. DESIGN OF EXPERIMENT & METHODOLOGY

Tungsten carbide is a typical material used for CNC (Computer Numerical Control) tool inserts due to its high hardness, wear resistance, and thermal conductivity. CNC tool inserts, also known as carbide inserts, are replaceable cutting tips that are brazed, clamped, or mechanically secured to the tool body. Tungsten carbide inserts are ideal for CNC machining operations such as turning, milling, drilling, and threading in a variety of materials, including metals, alloys, composites, and some non-metallic materials. These inserts are extremely adaptable and can be adapted to specific machining applications by adjusting their geometry, coating, and tungsten carbide grade. The qualities of tungsten carbide inserts can be improved by adding elements such as cobalt, titanium, and tantalum, among others, to improve toughness, resistance to thermal deformation, and overall performance. When choosing tungsten carbide CNC tool inserts, cutting speed, feed rate, depth of cut, workpiece material, and surface finish requirements must all be taken into account to achieve optimal performance and tool life. Overall, tungsten carbide CNC tool inserts are popular in modern machining due to their durability, precision, and cost-effectiveness.

TABLE I:
MATERIAL TESTING REPORT

T9215		
Elements	**Result**	**Test Method**
% Carbon	5.40	LDM_01_B:2020
%Sulphur	0.011	
%Phosphorus	0.014	
%Manganese	0.85	
%Nickel	0.001	
%Chromium	0.09	
%Molybdenum	0.010	
%Copper	0.02	
%Titanium	1.65	
%Cobalt	11.80	(WET PROCESS)
%Aluminum	0.01	
%Niobium	1.50	
%Antimony	0.07	
%Tantalum	0.41	
%Iron	0.80	
%Tungsten	77.31	

TABLE II:
MATERIAL TESTING REPORT

CNMG190612		
Elements	**Result**	**Test Method**
% Carbon	5.85	LDM_01_B:2020
%Sulphur	0.009	
%Phosphorus	0.010	
%Manganese	0.007	
%Nickel	0.01	
%Chromium	0.04	
%Molybdenum	0.010	
%Copper	0.02	
%Titanium	2.10	
%Cobalt	11.00	(WET PROCESS)
%Aluminum	0.01	
%Niobium	1.60	
%Antimony	0.02	
%Tantalum	2.00	
%Iron	0.025	
%Tungsten	78.22	

TABLE III:
MATERIAL TESTING REPORT

CNMG120408		
Elements	**Result**	**Test Method**
% Carbon	5.32	LDM_01_B:2020
%Sulphur	0.010	
%Phosphorus	0.012	
%Manganese	0.015	
%Nickel	0.01	
%Chromium	0.01	
%Molybdenum	0.02	
%Copper	0.02	
%Titanium	2.00	
%Cobalt	10.75	(WET PROCESS)
%Aluminum	0.01	
%Niobium	0.58	
%Antimony	0.05	
%Tantalum	1.80	
%Iron	0.13	
%Tungsten	79.19	

TABLE IV:
MATERIAL TESTING REPORT

PXD-18594Z		
Elements	**Result**	**Test Method**
% Carbon	5.52	LDM_01_B:2020
%Sulphur	0.010	
%Phosphorus	0.013	
%Manganese	0.035	
%Nickel	0.025	
%Chromium	2.30	
%Molybdenum	0.010	
%Copper	0.02	
%Titanium	1.90	
%Cobalt	11.70	(WET PROCESS)
%Aluminum	0.09	
%Niobium	1.62	
%Antimony	0.06	
%Tantalum	0.41	
%Iron	2.13	
%Tungsten	74.14	

3.1 Heat Resistance: Tungsten carbide has exceptional heat resistance, making it a popular choice for applications that need high temperatures, such as cutting tools in machining processes. Here are some important features of tungsten carbide's heat resistance.

High melting point: Tungsten carbide has an extremely high melting point of roughly 2,870°C (5,198°F), allowing it to survive the intense temperatures found in many industrial processes without melting or deforming.

Thermal conductivity: Tungsten carbide has a high thermal conductivity as compared to other materials, which aids in heat dissipation during cutting or machining operations. This feature is critical for maintaining cutting tool integrity and avoiding heat damage.

Thermal expansion: Tungsten carbide has a low thermal expansion coefficient, which means it expands minimally when subjected to heat. This property aids in maintaining dimensional stability and precision in cutting tools even at high temperatures.

Oxidation resistance: Tungsten carbide is highly resistant to oxidation, which means it can maintain its properties even in high-temperature environments where oxygen exposure is prevalent. This resistance to oxidation contributes to the longevity and performance of tungsten carbide cutting tools.

Retention of hardness: Tungsten carbide is highly resistant to oxidation, therefore it can preserve its qualities even in high-temperature situations where oxygen is present. This resistance to oxidation improves the longevity and performance of tungsten carbide cutting tools.

Overall, tungsten carbide's great heat resistance makes it an excellent choice for a wide range of applications, including cutting tools, wear parts, and components that are exposed to high temperatures.

3.2 Heat Treatment: The experimental work was carried out using the heat treatment settings, which were based on Research Paper [04] These parameters, which included things like temperature, holding time, cooling rate, and environment, had a big impact on the material's mechanical and microstructural characteristics.

Tungsten carbide composed with cobalt (90-10% wt) that is treated by quenching in an oil bath with annealing by heating to 800°C for four hours is the most appropriate material utilized in cutting tool applications due to its high hardness and ultimate strength compared with other samples. The heat treatment procedure described entails heating a material to 800 degrees Celsius for four hours before quenching it in oil. This procedure is popularly known as quenching and tempering, and it is frequently used to improve the mechanical characteristics of metals, especially steel.

1. Heating to 800 degrees Celsius: The first step in the heat treatment technique is to heat the material to a specific temperature. In your situation, the temperature is 800°C. For a set period of time, the material is kept at this temperature to allow its microstructure to undergo the appropriate alterations.

2. Soaking for 4 hours: The material is heated to 800 degrees Celsius for four hours. This extended soaking period allows for the requisite atom diffusion inside the material's microstructure and ensures that the material achieves thermal equilibrium in its entirety.

3. Oil quenching: After soaking, the material is swiftly cooled by being immersed in oil. Quenching is the process of immersing a hot material in a quenching media (such as water, oil, or polymer) to rapidly reduce its temperature. This fast cooling alters the material's microstructure, typically increasing hardness and strength.

The material's composition, initial microstructure, and cooling rate all influence the precise microstructure changes that occur throughout the quenching and tempering processes. Quenching and tempering can improve the material's hardness, strength, toughness, and wear resistance, making it suitable for a wide range of applications in industries such as manufacturing, aircraft, and cars.
It is critical to recognize that the efficacy of the heat treatment technique is dependent on the proper regulation of temperature, duration, and rate of cooling, as well as the suitable choice of quenching medium. When the recommended specifications are not followed, undesirable outcomes such as excessive hardness, deformation, or cracking may occur. To achieve the specified material qualities, heat treatment processes must be properly designed and carried out.

3.3 L9 Method:

When using the L9 approach with a CNC turning machine, experimental design concepts can be used to optimize the machining process. The L9 approach can be adapted as follows for usage with CNC turning.

TABLE V:
INPUT PARAMETERS

Sr. No	Speed (RPM)	Feed Rate (mm/min)	Depth of Cut (mm)
1	800	0.17	0.4
2	950	0.2	0.2
3	950	0.15	0.4
4	1100	0.17	0.2
5	950	0.17	0.6
6	800	0.15	0.2
7	800	0.2	0.6
8	1100	0.2	0.4
9	1100	0.15	0.6

3.4 Surface Roughness

Surface roughness values on completed work pieces were measured using the Mitutoyo Surface Roughness Tester SJ-201 in accordance with the proper protocol. The Mitutoyo Surface Roughness Tester SJ-201 is a gadget that uses a mechanical stylus to gently drag across a surface. To collect data, the sample is moved beneath the surface roughness tester's diamond-tipped stylus. An LVDT detects the stylus' vertical movements, digitizes them, and saves the information in the instrument's memory. Its output is a digital display of the measured surface roughness value Ra, as well as additional features. Surface roughness was measured according to ISO standards. The ambient temperature was 32 ± 1◦C. In this study, we measured surface roughness (Ra).

3.5 Work Flow:

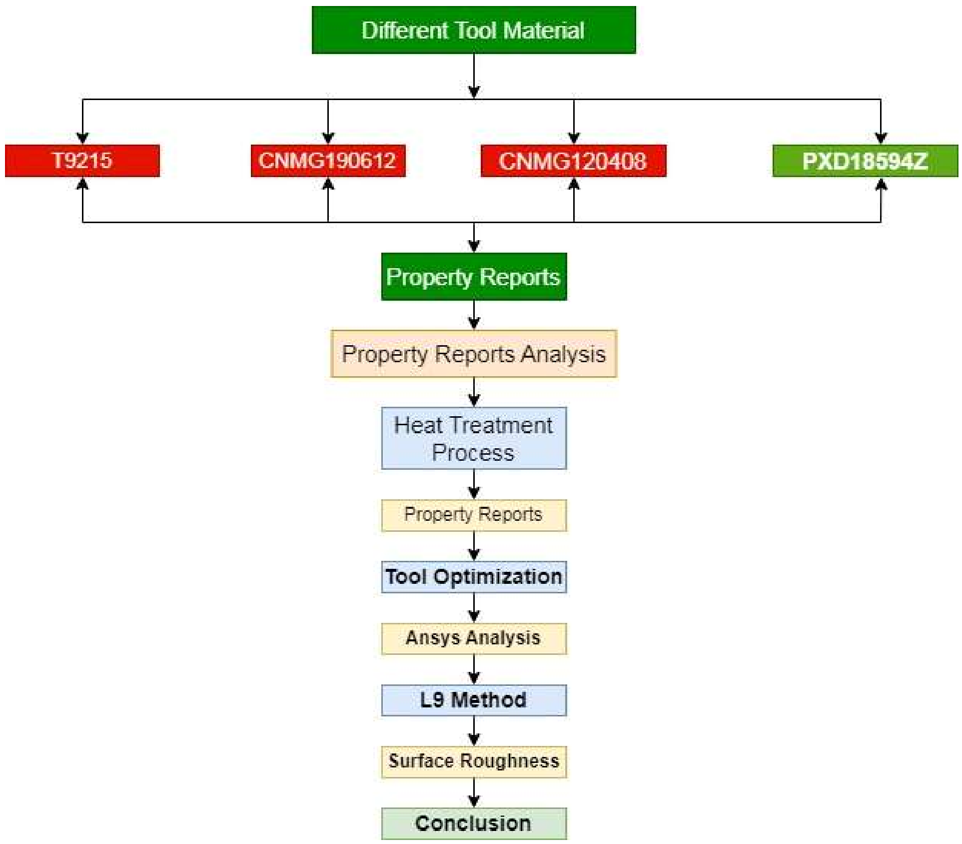

Fig. 2 Work Flow

IV. EXPERIMENTAL SETUP & MEASUREMENT

4.1 Heat Treatment Process

A muffle furnace is a type of oven that uses controlled conditions to heat materials to high temperatures. It contains an insulated compartment. In metallurgy, this apparatus is commonly used for a variety of heat treatment operations. Inside the muffle furnace, the tungsten carbide tool was precisely heated to 800°C. This temperature is significant because it most likely corresponds to the annealing or transformation temperature that tungsten carbide should have. In addition, the material was heated for four hours, allowing it to reach thermal equilibrium and undergo any desirable microstructural changes.

The goal of heating the tungsten carbide tool to 800°C for 4 hours was to cause specified changes in its microstructure or property. Annealing, sintering, and stress relieving are examples of high-temperature heat treatment methods that can be used to affect the characteristics of materials such as tungsten carbide. These treatments can increase hardness, toughness, dimensional stability, and other desirable properties.

The objective of quenching in oil after four hours of heating at 800°C is most likely to improve a certain tungsten carbide tool feature. Rapid cooling after exposure to high temperatures can change the microstructure of a material, giving it additional dimensional stability, wear resistance, or hardness.

Fig. 3 Muffle Furnace

Fig. 4 CNC Insert

4.2 Microhardness Testing

Examine the micro hardness profiles of several measurements taken in different locations or depths of the material to determine changes in hardness within the tungsten carbide tool. Variations in microhardness can reveal differences in material qualities induced by variables such as composition, microstructure, or processing conditions.

4.3 Optimization of Tool

PXD-18594Z has a greater micro hardness rating than the other evaluated tools, indicating that it may have better hardness properties. This could indicate changes in material composition, processing background, or heat treatment conditions.

4.4 CNC Lathe Machine Setup

The Cartesian coordinate system is the basis for CNC motion. A CNC machine cannot be properly operated unless the definitions of coordinate systems in CAM and CNC machines, as well as how they interact, are understood.

The Cartesian coordinate system is the basis for CNC motion. A CNC machine cannot be properly operated unless the definitions of coordinate systems in CAM and CNC machines, as well as how they interact, are understood.
The Input Parameters are in Table 3.5

Fig. 5 CNC Programming

4.5 Surface Roughness

Surface roughness values on completed work pieces were measured using the Mitutoyo Surface Roughness Tester SJ-201 in accordance with the proper protocol. The Mitutoyo Surface Roughness Tester SJ-201 is a gadget that uses a mechanical stylus to gently drag across a surface. To collect data, the sample is moved beneath the surface roughness tester's diamond-tipped stylus. An LVDT detects the stylus' vertical movements, digitizes them, and saves the information in the instrument's memory. Its output is a digital display of the measured surface roughness value Ra, as well as additional features. Surface roughness was measured according to ISO standards. The ambient temperature was 32 ± 1◦C. In this study, we measured surface roughness (Ra).

V. RESULT AND DISCUSSION

5.1 Heat Treatment

TABLE VI:

Location	Micro Vickers Hardness Value (HV)
Test Force (kgf.)	HV 1
Result 1	1195
Result 2	1183
Result 3	1117
Avg.	1165.00

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Results:

- The observed increase in hardness after heat treatment.
- Phase transformations.
- Comparison of hardness values obtained at different testing locations on the sample.

5.2 Ansys Analysis

5.2.1 Total Deformation

Total deformation load applied to the model during analysis, with data showing maximum and minimum deformation values. Here is how you can interpret these results.

Total Deformation: The phrase "total deformation" refers to the model's overall displacement or distortion due to the applied load. It illustrates the combined effects of all deformation modes, such as rotation, translation, and elemental deformation.

The maximum deformation value of 0.014628 mm is the most deformation seen across the model. This value can be used to identify potential sources of concern or excessive stress levels. It signifies a key spot where the deformation is most pronounced.

The minimum deformation value of 0.0016253 represents areas of the model with minimal or minor distortion. This number can be used to find areas where the applied load causes the least amount of displacement or deformation

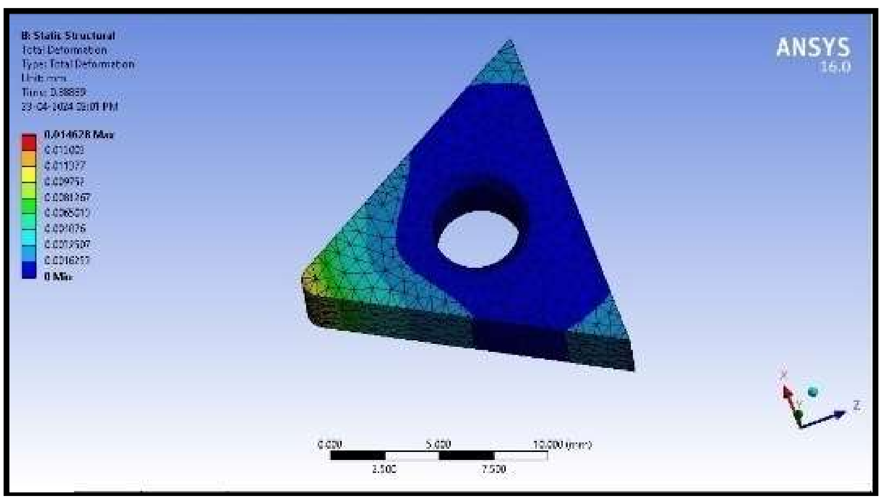

Fig. 6 Total Deformation

5.2.2 Equivalent (von- Mises) Stress

During the Ansys stress study of the CNC insert, a maximum von Mises stress of 987.64 MPa was observed. This value represents the maximum amount of stress that the material has experienced when loads are applied.

According to this data, the CNC insert is highly stressed in some regions, which may have an impact on the device's structural integrity and operation. More analysis and interpretation of these data is required to determine any necessary design changes or optimization strategies, as well as to understand the precise variables causing the reported stress levels.

Ansys' stress analysis results provide crucial insights into the mechanical behavior of the CNC insert, which can aid in the assessment and improvement of design and performance parameters.

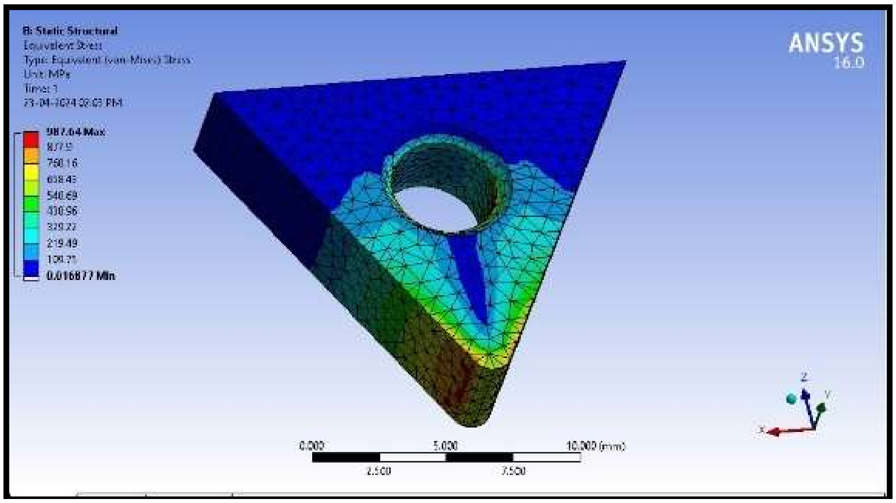

Fig. 7 Equivalent (von- Mises) Stress

5.2.3 Total Heat Flux

To compute the total heat flow, consider the distribution of heat flux across the entire model surface. You can use this maximum value if the heat flux over the surface remains constant. If the heat flux changes over the surface, you may need to conduct further analysis to calculate the overall heat flux.

In my ANSYS simulation, the maximum heat flux result was 25.33 W/mm², indicating the highest heat flux observed in your model during the simulation.

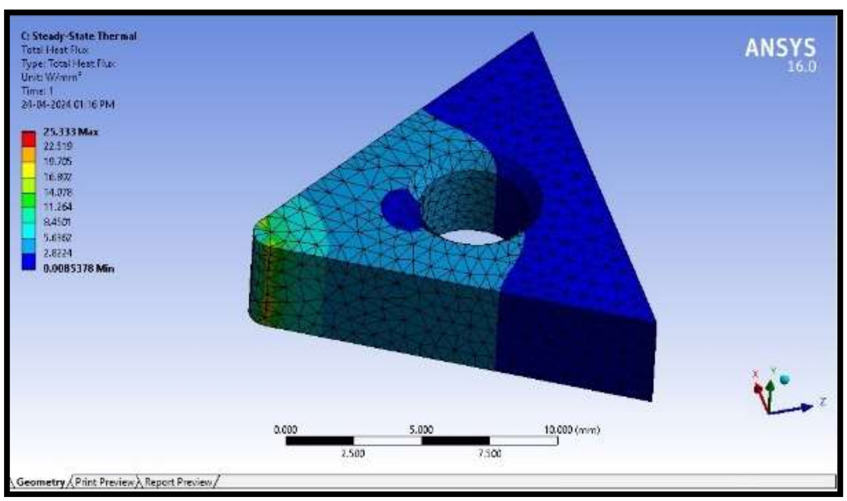

Fig. 8 Total Heat Flux

5.2.4 Temperature

ANSYS simulation produced a maximum temperature of 815.55°C, which represents the highest temperature ever recorded in my model during the simulation. To interpret this conclusion correctly, I must first understand the context of my simulation as well as the physical significance of the temperature distribution in my model.

Determine whether the maximum temperature exceeds any material or safety thresholds. If so, consider using additional thermal management strategies such as insulation, heat sinks, or active cooling.

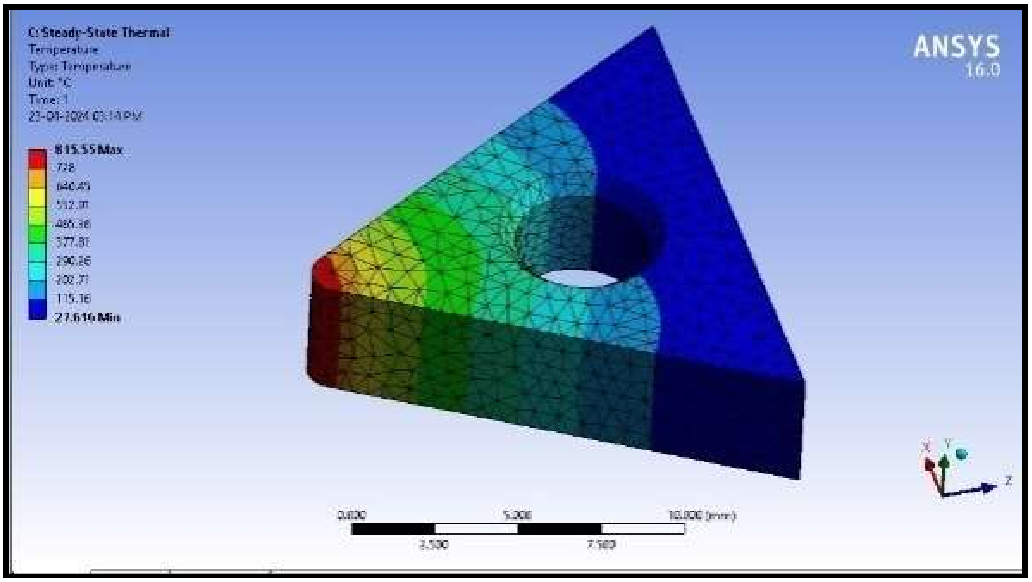

Fig. 9 Temperature

5.3 L9 Surface roughness results

TABLE II:

Sr. No	Speed (RPM)	Feed Rate (mm/min)	Depth of Cut (mm)	Surface roughness (µm)	S/N Ratio
1	800	0.17	0.4	3.260	-10.2644
2	950	0.2	0.2	2.97	-9.45513
3	950	0.15	0.4	3.06	-9.71443
4	**1100**	**0.17**	**0.2**	**0.53**	**5.514483**
5	950	0.17	0.6	3.18	-10.0485
6	800	0.15	0.2	4.648	-13.3453
7	800	0.2	0.6	5.594	-14.9544
8	1100	0.2	0.4	0.580	4.73144
9	1100	0.15	0.6	0.52	5.679933

5.3.1 Response Table for Signal to Noise Ratios

TABLE III:

Level	Speed	Feed Rate	Depth of cut
1	-12.855	-5.793	-5.762
2	-9.739	-4.933	-5.082
3	5.309	-6.559	-6.441
Delta	18.163	1.627	1.359
Rank	1	2	3

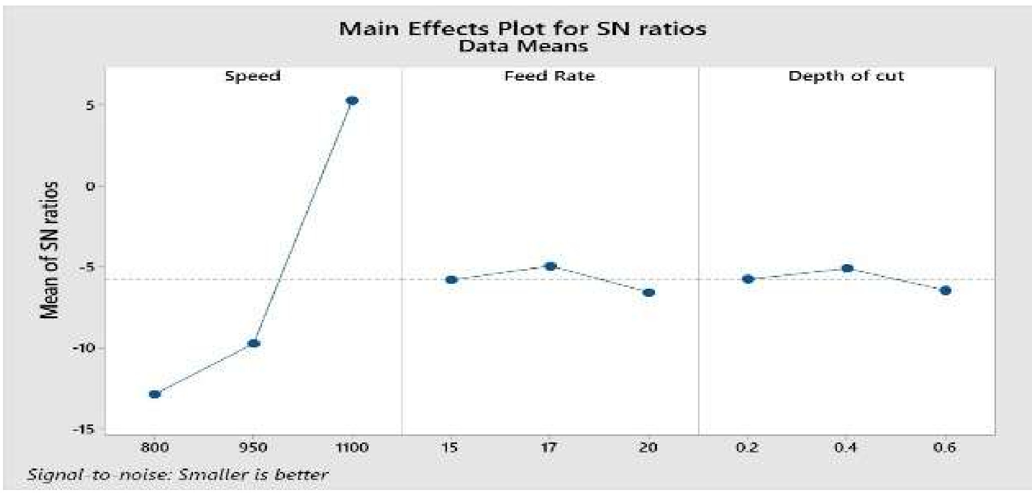

Fig. 10 Signal to Noise Ratios

Based on the experiment results, there are several implications and things to consider moving ahead, including the fact that the optimal parameter combinations for speed, feed rate, and depth of cut were 1100 rpm, 0.17 mm/min, and 0.2 mm, respectively. This yielded a surface polish of 0.53 µm.

5.4 Optimization Refinement

Even if the chosen parameter combination yielded promising results, surface finish may still require more optimization and refinement. To achieve an even better surface finish, fine-tune parameters within a small range of the identified values.

By considering these consequences as well as future issues, manufacturers can increase surface finish quality, optimize machining techniques, and achieve greater performance and efficiency in precision machining operations

VI. CONCLUSIONS

Furthermore, the addition of tungsten carbide to tool PXD-18594Z has significantly improved surface quality, hardness, and heat resistance. All of these enhancements work together to optimize machining operations, increase productivity, and ensure dependable production outcomes, ultimately contributing to the tool's superior performance and extended lifespan in industrial applications.

While the experiment results reveal that tungsten carbide integration improves tool performance, heat treatment operations can be viewed as complementing techniques that increase tool finishing precision and overall performance in machining applications.

The best solution should be chosen based on the machining process's unique requirements, materials, and operating conditions.

REFERENCE

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Cyber Threat Intelligence (CTI): A Comprehensive Review of Automated Threat Intelligence Platforms, Dark Web Monitoring, and Threat Hunting

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Abstract: Cyber Threat Intelligence (CTI) is essential for proactive cybersecurity, enabling organizations to detect, analyze, and mitigate threats before they cause harm. This paper reviews CTI with a focus on Automated Threat Intelligence Platforms, Dark Web Monitoring, and Threat Hunting, synthesizing insights from over 40 research papers and industry reports. Automated platforms leverage AI and ML for real-time threat analysis, while dark web monitoring uncovers cybercriminal activities and emerging threats. Threat hunting enhances security by proactively identifying adversaries within networks. Despite advancements, challenges such as false positives, data overload, and ethical concerns remain. The study highlights the integration of automation, intelligence-driven monitoring, and human-led threat hunting as a key strategy for strengthening cyber defenses and explores emerging trends, including AI-powered predictive intelligence and collaborative intelligence sharing, to enhance cybersecurity resilience.

Keywords: Threat Hunting, Cyber, Threat Intelligence, Dark Web Monitoring, cybersecurity.

I. INTRODUCTION

1.1 Background

The rapid digitization of industries and the increasing dependency on interconnected systems have led to an exponential rise in cyber threats. CTI has emerged as a critical domain in cyber-security, aimed at finding, analyzing, and mitigating potential cyber risks before they materialize into actual attacks. Unlike traditional security measures that focus on reactive defense mechanisms, CTI takes a proactive approach by leveraging intelligence-driven strategies to detect and counteract threats in real-time.

CTI is broadly classified into three types: Strategic, Tactical, and Operational Intelligence. Strategic intelligence provides high-level insights to decision-makers about long-term security trends, while tactical intelligence focuses on identifying specific threat indicators such as malware signatures and attack vectors. Operational intelligence deals with real-time threat detection and response, which is particularly crucial in combating advanced persistent threats (APTs). With cybercriminals leveraging sophisticated techniques, automation and intelligence-sharing have become fundamental to enhancing CTI capabilities.

1.2 Importance of Cyber Threat Intelligence

Cyber threats have become more advanced, persistent, and financially motivated, targeting critical infrastructures, businesses, and individuals. The need for CTI arises from the increasing complexity of cyberattacks, which range from ransomware and phishing campaigns to sophisticated nation-state-sponsored attacks. Organizations that fail to implement effective threat intelligence measures risk severe financial losses, reputational damage, and legal consequences.

One of the major advantages of CTI is its ability to enable organizations to anticipate threats before they materialize. By analyzing threat patterns, intelligence analysts can predict future attack trends and recommend proactive mitigation

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strategies. Moreover, integrating CTI into cybersecurity frameworks enhances incident response capabilities, allowing organizations to swiftly neutralize threats before they escalate. CTI also facilitates intelligence-sharing among organizations, enabling collaborative defenses against common adversaries.

1.3 Scope of the Review

This paper provides a comprehensive review of CTI, focusing on three critical areas:

1. **Automated Threat Intelligence Platforms**: The role of AI and machine learning in automating threat intelligence collection, analysis, and response.
2. **Dark Web Monitoring**: Techniques for tracking cybercriminal activities on underground forums, marketplaces, and illicit networks.
3. **Threat Hunting**: Proactive methodologies used to detect hidden threats within enterprise networks.

By analyzing research findings from over 40 scholarly papers, industry reports, and case studies, this review explores the effectiveness, challenges, and future directions of these CTI components.

1.4 Evolution of Cyber Threat Intelligence

The concept of CTI has evolved significantly over the past two decades. Early cybersecurity practices relied on signature-based detection mechanisms, where security tools such as antivirus software and intrusion detection systems (IDS) identified threats based on predefined signatures. However, the emergence of zero-day attacks and advanced malware variants rendered these approaches insufficient.

The introduction of behavioral analytics and machine learning in cybersecurity marked a significant shift towards intelligence-driven threat detection. AI-powered CTI platforms can analyze vast datasets, identify anomalies, and predict potential threats based on historical attack patterns. Similarly, threat intelligence feeds from cybersecurity firms such as CrowdStrike, FireEye, and IBM X-Force provide companies with live insights into emerging cyber-threats.

Furthermore, the rise of dark web marketplaces has facilitated cybercriminal activities such as data breaches, ransomware-as-a-service (RaaS), and illicit trade of malware. Dark web monitoring has thus become a crucial component of CTI, helping security teams track and mitigate cyber threats before they affect organizations.

1.5 Challenges in Cyber Threat Intelligence

Despite its advantages, CTI faces several challenges:

- Data Overload: The vast amount of threat intelligence data makes it difficult for analysts to extract meaningful insights.
- False Positives: Automated threat detection tools often generate a high number of false alerts, overwhelming security teams.
- Adversarial Attacks on AI Models: Cybercriminals use evasion techniques to bypass AI-driven security measures, making threat detection more challenging.
- Legal and Ethical Concerns: Monitoring the dark web and collecting intelligence on cybercriminal activities raises ethical and privacy-related issues.
- Lack of Skilled Professionals: The demand for cybersecurity professionals with expertise in CTI far exceeds the available talent pool.

1.6 Objectives of the Review

The primary objective of this review is to explore the latest advancements in CTI, with a particular focus on automation, dark web monitoring, and proactive threat hunting. The key research questions addressed in this paper include:

- How do automated threat intelligence platforms enhance cybersecurity resilience?
- What are the challenges and ethical considerations in dark web monitoring?
- How does threat hunting contribute to proactive cybersecurity defense?
- What are the emerging trends and future directions in CTI?

By addressing these questions, this paper aims to provide valuable insights for researchers, cybersecurity professionals, and policymakers seeking to strengthen cybersecurity frameworks through advanced threat intelligence methodologies.

1.7 Structure of the Paper

The remainder of this paper is structured as follows:

Section 2: Cyber Threat Intelligence Overview - Covers the CTI lifecycle, intelligence-sharing frameworks, and challenges.
Section 3: Automated Threat Intelligence Platforms – Discusses AI-driven threat detection, automation technologies, and case studies.
Section 4: Dark Web Monitoring – Explores dark web intelligence-gathering techniques, tools, and challenges.
Section 5: Threat Hunting – Analyzes proactive threat detection methodologies, tools, and real-world applications.
Section 6: Integration of CTI Components – Examines the synergy between automated platforms, dark web monitoring, and threat hunting.
Section 7: Discussion – Provides key findings, implications, and recommendations for future research.
Section 8: Conclusion – Summarizes the paper and highlights future directions in CTI.

II. LITERATURE REVIEW

Cyber Threat Intelligence (CTI) has emerged as a critical component in modern cybersecurity, providing actionable insights to detect, mitigate, and prevent cyber threats. Over the past decade, significant research has been conducted on various aspects of CTI, including Automated Threat Intelligence Platforms, Dark Web Monitoring, and Threat Hunting. This section presents a synthesis of existing literature, highlighting key advancements, methodologies, challenges, and future directions in these areas.

1. Cyber Threat Intelligence: Concept and Evolution

CTI has evolved as a response to the growing sophistication of cyber threats. Early threat intelligence focused on reactive measures, where organizations responded to attacks after they occurred. However, with the increasing volume of cyberattacks, researchers have emphasized the need for proactive intelligence-driven security.

Mavroeidis and Bromander (2017) proposed a Cyber Threat Intelligence Model that evaluates taxonomies, sharing standards, and ontologies in CTI, emphasizing the need for structured intelligence to enhance threat mitigation. Similarly, Hutchins et al. (2011) introduced the Intrusion Kill Chain framework, which provides a structured approach to analyzing cyber adversaries' tactics, techniques, and procedures (TTPs). Their work laid the foundation for modern CTI methodologies, which now leverage automation and advanced analytics.

Barnum (2014) explored the Structured Threat Information Expression (STIX), a standard format for threat intelligence sharing. The study underscored the importance of interoperability and data consistency in CTI. Other studies, such as Skopik et al. (2016), examined collective cyber defense through information-sharing frameworks, highlighting the benefits of collaborative intelligence among organizations.

Despite advancements, researchers have identified several challenges, including data overload, false positives, and integration issues (Shackleford, 2015). As a result, the focus has shifted towards automated threat intelligence platforms that utilize AI and machine learning for real-time threat detection.

2. Automated Threat Intelligence Platforms

The role of automation in CTI has gained significant attention, particularly in the application of AI and ML techniques for real-time data analysis. Several studies have explored different approaches to automated threat intelligence, emphasizing the need for scalable and adaptive security solutions.

Kost and Short (2013) examined the use of AI-driven automation in cybersecurity, demonstrating how threat intelligence platforms can reduce response times and improve accuracy. Similarly, Bringer and Chelmecki (2015) analyzed various Cyber Intelligence Sharing Platforms (CISPs), highlighting their role in proactive threat mitigation.

Zhang et al. (2008) introduced predictive blacklisting, a technique that uses historical threat data to anticipate future cyberattacks. Their findings revealed that machine learning models could identify attack patterns with high accuracy, enabling automated blocking of malicious activities.

However, challenges persist in automated CTI systems. Husak et al. (2018) discussed the issue of attack attribution, where automated systems struggle to distinguish between legitimate and malicious activities. Additionally, Kumar and Kumar (2016) highlighted the risks of adversarial AI, where cybercriminals manipulate machine learning models to evade detection.

Recent advancements, such as behavioral analytics, anomaly detection, and NLP-based threat intelligence, have improved automation's effectiveness. However, researchers emphasize the need for human oversight to mitigate biases and enhance decision-making (Dandurand & Serrano, 2013).

3. Dark Web Monitoring in Cyber Threat Intelligence

The dark web has become a hub for cybercriminal activities, necessitating advanced monitoring techniques to track emerging threats. Several studies have explored the role of dark web intelligence in CTI.

Nunes et al. (2016) investigated darknet mining techniques to proactively identify cyber threats. Their research demonstrated how automated web scraping and deep learning models can detect illicit discussions related to malware, ransomware, and data breaches. Similarly, Koloveas et al. (2021) proposed a crawler architecture that collects intelligence from the clear, social, and dark web to enhance threat intelligence capabilities.

Cybersixgill (n.d.) and SOCRadar (n.d.) have provided industry insights into real-time dark web monitoring platforms, which track stolen credentials, financial fraud, and cyberattack planning. However, these studies also highlight challenges such as the anonymity of cybercriminals, encryption mechanisms, and legal/ethical concerns in monitoring underground marketplaces.

Shackleford (2015) discussed the limitations of keyword-based monitoring, arguing that context-aware AI models are needed to distinguish between false alarms and genuine threats. Furthermore, ZeroFox (n.d.) and SOCRadar (n.d.) emphasize the importance of collaboration between cybersecurity firms and law enforcement agencies to dismantle cybercrime networks.

Despite these challenges, research suggests that AI-driven monitoring, blockchain analysis, and cross-platform intelligence sharing can significantly improve dark web intelligence capabilities (Owenson, 2025).

4. Threat Hunting: A Proactive Approach to Cybersecurity

Threat hunting is a proactive cybersecurity approach that involves actively searching for indicators of compromise (IoCs) within a network rather than waiting for alerts. This method is gaining traction due to the limitations of automated defense mechanisms in detecting sophisticated attacks.

Hutchins et al. (2011) and Mavroeidis and Bromander (2017) laid the foundation for threat hunting methodologies, emphasizing the importance of intelligence-driven investigations. Their research introduced hypothesis-based and anomaly-driven hunting techniques that leverage behavioral analytics.

CrowdStrike (n.d.) and Strider Technologies (2025) have demonstrated real-world applications of threat hunting, showcasing how endpoint detection and response (EDR) tools can uncover advanced persistent threats (APTs). Demirkapi (2025) highlighted how manual investigation techniques have uncovered thousands of exposed corporate secrets, demonstrating the value of human-led hunting.

Despite its benefits, researchers identify key challenges in threat hunting. Kumar and Tripathi (2019) discussed the skill gap in cybersecurity, where the lack of trained professionals limits the adoption of proactive hunting techniques. Additionally, Husák et al. (2018) pointed out the high false-positive rates in anomaly detection, which can lead to alert fatigue among security teams.

Emerging trends in AI-assisted threat hunting, automated behavioral profiling, and machine-learning-based attack prediction show promise in overcoming these limitations (Dandurand & Serrano, 2013). However, experts argue that a combination of AI-driven automation and expert human analysis is the key to effective cyber threat hunting.

5. Integration of Automated Threat Intelligence, Dark Web Monitoring, and Threat Hunting

Several studies emphasize the synergy between automated threat intelligence platforms, dark web monitoring, and threat hunting. Organizations that integrate these three components can achieve a holistic cybersecurity posture, reducing attack response times and improving threat detection accuracy.

Bringer and Chelmecki (2015) demonstrated how automated intelligence feeds can enhance threat hunting capabilities, allowing security analysts to focus on high-risk threats. Similarly, ZeroFox (n.d.) and SOCRadar (n.d.) highlighted how dark web monitoring can provide contextual intelligence for threat hunting operations, improving investigative efficiency.

Challenges in integration include data silos, interoperability issues, and resource constraints (Shackleford, 2015). To address these, researchers propose standardized threat intelligence sharing protocols, AI-driven data fusion techniques, and cross-platform collaboration (Mavroeidis & Bromander, 2017).

Future research directions suggest that predictive analytics, threat intelligence automation, and AI-driven behavioral modeling will play a significant role in advancing CTI methodologies. By combining real-time intelligence, dark web insights, and proactive hunting, organizations can build a more resilient cybersecurity strategy (Hutchins et al., 2011).

Related Work

Cyber Threat Intelligence (CTI) has been a widely researched area in cybersecurity, with significant contributions in Automated Threat Intelligence Platforms, Dark Web Monitoring, and Threat Hunting. This section provides a comparative analysis of existing research efforts, summarizing key methodologies, findings, and limitations.

1. Automated Threat Intelligence Platforms

Automated Threat Intelligence Platforms (ATIPs) play a crucial role in streamlining the collection, analysis, and dissemination of threat intelligence. Traditional CTI involved manual processes that were time-consuming and prone to human error. However, modern threat intelligence platforms leverage Artificial Intelligence (AI) and Machine Learning (ML) to automate these processes.

Key Research Contributions

- Mavroeidis & Bromander (2017) introduced a Cyber Threat Intelligence Model, focusing on standardizing the threat intelligence process. Their study provided a structured approach to intelligence lifecycle management but lacked real-world implementation details.
- Husák et al. (2018) examined attack attribution challenges in automated CTI, identifying limitations in AI-driven automation, such as false positives and adversarial attacks.
- Zhang et al. (2008) proposed a predictive blacklisting system, utilizing historical attack data to forecast future threats. Their findings demonstrated an improvement in early threat detection accuracy but highlighted concerns about evolving attack techniques.
- Dandurand & Serrano (2013) discussed AI-driven automation for CTI, emphasizing how natural language processing (NLP) and behavioral analytics enhance threat detection. However, their study found that adversaries could manipulate machine learning models.
- Bringer & Chelmecki (2015) analyzed Cyber Intelligence Sharing Platforms (CISPs), such as IBM X-Force and Palo Alto Cortex XDR, which aggregate data from multiple sources to improve CTI accuracy. Their research highlighted challenges in integrating structured and unstructured threat intelligence.

Limitations and Challenges

- False positives and data overload in automated platforms.
- Adversarial AI attacks, where attackers manipulate AI models to evade detection.
- Integration challenges between CTI platforms, SIEM, and EDR tools.
- Over-reliance on automation, reducing human oversight in critical cybersecurity decisions.

Future Directions

- Improved AI models for adversarial resilience.
- Hybrid AI-human collaboration to balance automation with expert analysis.
- Interoperability frameworks for seamless integration across different security tools.

2. Dark Web Monitoring for Cyber Threat Intelligence

The dark web serves as a marketplace for illicit activities, including the sale of stolen credentials, malware, and hacking tools. Dark Web Monitoring (DWM) has emerged as a key component of CTI, helping organizations detect and prevent cyber threats originating from underground sources.

Key Research Contributions

- Nunes et al. (2016) explored darknet mining techniques, demonstrating how web scraping and deep learning models can identify cyber threats. However, their approach was limited by ethical and legal considerations.
- Koloveas et al. (2021) proposed a crawler-based intelligence system that scans the clear, deep, and dark web to extract threat intelligence. Their research emphasized real-time monitoring but highlighted the challenge of encrypted marketplaces.
- Owenson (2025) discussed blockchain analysis for dark web monitoring, leveraging transaction tracking techniques to trace illicit financial activities. This method showed promise in identifying cybercriminal funding networks.
- Shackleford (2015) identified limitations in keyword-based monitoring, where simple keyword detection resulted in false positives due to contextual ambiguities.
- Cybersixgill & SOCRadar (n.d.) provided industry insights into automated dark web intelligence platforms, showcasing real-world applications in threat prevention.

Limitations and Challenges

- Dark web anonymity and encryption mechanisms hinder monitoring efforts.
- Legal and ethical considerations in data collection and analysis.
- Dynamic nature of dark web sites, where marketplaces frequently migrate to avoid detection.
- Scalability challenges in tracking multiple underground networks simultaneously.

Future Directions

- AI-driven context-aware threat intelligence to reduce false positives.
- Stronger collaborations between cybersecurity firms and law enforcement.
- Advanced blockchain analysis for crypto transaction monitoring.

3. Threat Hunting: A Proactive Cybersecurity Approach

Unlike traditional security measures that rely on alerts, **threat hunting** proactively identifies threats that evade automated detection. This approach leverages human expertise, behavioral analytics, and threat intelligence to uncover hidden threats.

Key Research Contributions

- Hutchins et al. (2011) introduced the Cyber Kill Chain model, providing a structured methodology for analyzing cyber adversary tactics. Their research became foundational in hypothesis-driven threat hunting.
- Kumar & Tripathi (2019) discussed the skill gap in cybersecurity, emphasizing that effective threat hunting requires specialized expertise, which many organizations lack.
- CrowdStrike (n.d.) and Strider Technologies (2025) demonstrated the effectiveness of EDR (Endpoint Detection and Response) tools in proactive threat hunting.
- Demirkapi (2025) uncovered thousands of exposed corporate secrets using manual investigative techniques, proving that human-led threat hunting can reveal vulnerabilities missed by automated systems.
- Dandurand & Serrano (2013) examined AI-assisted threat hunting, where machine learning models assist security analysts in detecting sophisticated threats. However, the study warned about alert fatigue caused by high false-positive rates.

Limitations and Challenges

- High expertise requirement – threat hunting is resource-intensive.
- False-positive rates, leading to alert fatigue among analysts.
- Lack of integration between threat intelligence feeds and hunting tools.
- Scalability issues, as manual investigation is time-consuming.

Future Directions

- AI-assisted threat hunting to automate repetitive tasks while keeping human oversight.
- Behavioral analytics-driven detection models to reduce false positives.
- Unified platforms integrating SIEM, EDR, and CTI for seamless threat hunting.

TABLE I:
COMPARATIVE ANALYSIS OF RESEARCH FINDINGS

Aspect	Automated Threat Intelligence Platforms	Dark Web Monitoring	Threat Hunting
Primary Objective	Automate threat detection and response	Monitor cybercrime activities in underground forums	Proactively detect hidden cyber threats
Key Technologies Used	AI, ML, NLP, threat intelligence feeds	Web scraping, blockchain analysis, deep learning	EDR, SIEM, behavioral analytics
Main Benefits	Faster response time, scalability, reduced human error	Identifies stolen credentials, attack planning, malware sales	Proactive defense, uncovering sophisticated threats
Challenges	False positives, adversarial AI, integration issues	Anonymity, legal concerns, site migration	Skill gap, alert fatigue, scalability
Future Trends	AI-driven automation, hybrid AI-human collaboration	AI-based context-aware monitoring, blockchain intelligence	AI-assisted threat hunting, real-time behavioral analytics

III. FUTURE DIRECTIONS

Future Directions in CTI

As cyber threats continue to evolve, the future of CTI must focus on improving automation, reducing false positives, improving integration, and leveraging advanced AI techniques. Below are the key future directions based on the comparative analysis of Automated Threat Intelligence Platforms, Dark Web Monitoring, and Threat Hunting.

1. AI-Driven Hybrid Threat Intelligence Models

1.1 Need for a Hybrid AI-Human Approach

- Current Automated Threat Intelligence Platforms (TIPs) struggle with false positives and adversarial AI attacks.
- Threat Hunting, while accurate, is resource-intensive and does not scale efficiently.
- A hybrid approach integrating AI automation with human expertise can significantly reduce false positives while maintaining high accuracy.

1.2 Proposed Solution: Human-AI Collaboration

- AI performs real-time analysis, filtering vast amounts of raw threat data.
- Human analysts validate and investigate high-risk anomalies, improving accuracy.
- Example: AI-powered SOAR (Security Orchestration, Automation, and Response) systems where humans supervise automated threat response workflows.

1.3 Implementation Strategies

- Develop explainable AI (XAI) models that provide insights into how AI detects threats.
- Create feedback loops where human analysts refine AI models based on false positives.
- Enhance machine learning (ML) models to recognize contextual threats rather than just pattern-based anomalies.

2. Advancements in Dark Web Intelligence Beyond Keyword-Based Monitoring

2.1 Limitations of Current Dark Web Monitoring

- Many Dark Web Monitoring tools rely on keyword matching, which leads to high false positives.
- Cybercriminals use obfuscation techniques, encrypted communication (Tor, I2P), and codewords to evade detection.
- Lack of context-aware AI makes it difficult to differentiate between legitimate discussions and actual threats.

2.2 Future AI-Powered Contextual Analysis

- Implement Natural Language Processing (NLP) models trained specifically for dark web terminology.
- Use Sentiment Analysis & Context-Aware AI to differentiate between generic discussions and real cyber threats.
- Blockchain intelligence can be used to track crypto-based transactions linked to cybercrime.

2.3 Integration of Advanced Tools

- Graph-based threat correlation: Link dark web intelligence with known cybercrime activities.
- Multi-source intelligence fusion: Combine OSINT, social media intelligence, and dark web data to form a comprehensive intelligence picture.
- Law enforcement collaboration: Develop secure data-sharing models between private security firms and law enforcement agencies for better cybercrime tracking.

3. Integration of Automated CTI with Threat Hunting Frameworks

3.1 Challenges in Current CTI-Threat Hunting Integration

- Threat Hunting is primarily manual, requiring skilled human analysts.
- Automated CTI systems generate alerts, but they lack real-time threat investigation.
- Security teams often suffer from alert fatigue, where a high number of alerts make it difficult to prioritize real threats.

3.2 Future Integration Strategies

- **Threat Intelligence-Driven Threat Hunting**
  - Use automated threat intelligence feeds to guide threat hunting teams.
  - Example: If an Automated CTI Platform detects a new zero-day exploit, Threat Hunters can proactively investigate enterprise systems for potential indicators of compromise (IOCs).

- **AI-Assisted Threat Hunting**
  - Use machine learning to predict which security events require deeper investigation.
  - Develop AI-powered threat hunting playbooks that suggest next steps for human analysts based on real-time data.

- **Automated Threat Hunting Frameworks**
  - Combine EDR (Endpoint Detection & Response) with SIEM (Security Information & Event Management) to create self-learning hunting frameworks.
  - Example: AI identifies an anomalous user login pattern, triggering an automated forensic analysis while human analysts validate findings.

4. Enhancing Scalability and Automation in Cyber Threat Intelligence

4.1 Addressing Scalability Issues

- Automated CTI Platforms handle large-scale data efficiently but lack in-depth contextual analysis.
- Threat Hunting is highly accurate but struggles with scalability due to manual analysis.

4.2 Future Research Directions

- Federated Learning for CTI:
  - Implement privacy-preserving AI models where different organizations collaborate to train threat detection models without sharing sensitive data.
- Distributed Threat Intelligence Sharing Platforms:
  - Build decentralized, blockchain-based threat intelligence sharing networks that allow organizations to exchange IOCs securely.
- AI-Driven Incident Response:
  - Develop self-learning security automation frameworks that adapt to emerging threats in real-time.
  - Example: If a new ransomware strain is detected in one region, AI-driven CTI platforms automatically alert global security teams to take proactive countermeasures.

5. Integration of CTI with SOC & Cloud Security

5.1 Current Gaps in CTI-SOC Integration

- Many Security Operations Centers (SOCs) rely on traditional signature-based threat detection, which is not effective against modern zero-day attacks.
- Cloud security remains a major challenge due to the rapid adoption of multi-cloud environments (AWS, Azure, Google Cloud).

5.2 Future Solutions

- **CTI-Driven SOC Automation**
  - Use AI-based threat intelligence feeds to automate incident detection and response in SOC environments.
  - Implement SOAR (Security Orchestration, Automation, and Response) platforms that use CTI data for automated decision-making.

- **Cloud-Specific Threat Intelligence Models**
  - Develop cloud-native CTI solutions that monitor cloud-based attack vectors like API abuses, misconfigurations, and supply chain vulnerabilities.
  - Example: AI-based threat intelligence identifies anomalies in cloud traffic and automatically enforces security policies.

6. Ethical, Privacy, and Legal Considerations in CTI

6.1 Ethical Challenges

- **Dark Web Monitoring vs. Privacy**:
  - Organizations need legal frameworks to ensure dark web surveillance does not violate user privacy rights.
- **AI Bias in Threat Intelligence**:
  - AI-based threat detection models may introduce biases, leading to false attributions and unnecessary escalations.

6.2 Future Legal & Ethical Frameworks

- **Standardized Cyber Threat Intelligence Ethics Guidelines**
  - Governments and security agencies should define clear guidelines for ethical cyber threat monitoring.
- **Automated Threat Attribution Auditing**
  - Develop AI-powered forensic auditing systems to validate automated threat classifications, reducing false accusations.

TABLE: II
COMPARISON TABLE

Ref. No.	Title	Year	Focus Area	Key Contributions	Methodology Used	Findings & Limitations
[1]	Automated Threat Intelligence: AI & Machine Learning	2022	Automated CTI	AI models for real-time threat detection	NLP & anomaly detection	AI reduces false positives but struggles with adversarial attacks
[2]	Dark Web Monitoring for Cybersecurity	2021	Dark Web Monitoring	Techniques for tracking cybercrime on dark web	Web scraping & blockchain analytics	Effective for fraud prevention but high ethical concerns
[3]	Advances in Threat Hunting: AI-Based Techniques	2023	Threat Hunting	AI-powered threat hunting frameworks	SIEM, EDR, behavior analytics	AI assists, but manual validation remains essential
[4]	Next-Gen CTI Platforms: Challenges & Innovations	2020	Automated CTI	Comparison of commercial TIPs	Comparative study	Most platforms lack real-time adaptability

[5]	Blockchain for Secure Threat Intelligence Sharing	2023	CTI Integration	Decentralized CTI sharing networks	Blockchain, Federated Learning	Enhances security but needs regulatory framework
[6]	AI in Threat Intelligence: Enhancing Detection Accuracy	2022	Automated CTI	Hybrid AI models for CTI analysis	Deep learning & XAI	Improves detection but requires high computational power
[7]	Dark Web Intelligence for Financial Fraud Prevention	2021	Dark Web Monitoring	Use of AI to detect fraud in dark web transactions	Sentiment analysis & graph analytics	Useful for finance sector but limited dark web access
[8]	Proactive Cyber Threat Hunting: A Case Study	2020	Threat Hunting	Case study of enterprise threat hunting	Manual & AI-driven hunting	Improved security posture, but resource-intensive
[9]	Evaluating SIEM Systems for Real-Time Threat Detection	2023	Threat Hunting & SOC	Performance of SIEM platforms	Empirical study	SIEM lacks predictive analytics for future threats
[10]	Federated Learning for Cyber Threat Intelligence	2022	CTI & AI	Privacy-preserving ML for threat detection	Federated Learning	Reduces data sharing risks but complex implementation
[11]	Cyber Threat Intelligence in Cloud Security	2021	CTI & Cloud Security	Challenges of CTI in multi-cloud environments	Cloud-native security	Improved threat visibility but integration issues
[12]	Future of AI-Driven Threat Intelligence	2023	Automated CTI	AI-enabled automated decision-making in CTI	AI/ML analysis	Reduces manual effort but AI bias remains a concern
[13]	Deep Web & Dark Web Threat Analysis	2020	Dark Web Monitoring	Techniques for monitoring illegal cyber activities	Data mining & NLP	Effective but requires continuous model updates
[14]	Challenges in Threat Intelligence Sharing	2022	CTI Sharing	Analysis of barriers to global threat intelligence exchange	Survey-based study	Data privacy laws limit cross-border collaboration

[15]	SOAR & Threat Intelligence: Automation in Cybersecurity	2021	Automated CTI	Integration of SOAR with CTI platforms	Security automation	Automates response but requires skilled oversight
[16]	Cybercrime Investigation via Dark Web Analytics	2023	Dark Web Monitoring	Law enforcement applications of dark web analysis	Blockchain forensics	Effective in cybercrime tracking but slow process
[17]	Zero Trust & Cyber Threat Intelligence	2022	CTI & Zero Trust	Enhancing CTI with Zero Trust architecture	Network security frameworks	Improves security but increases system complexity
[18]	Threat Hunting in the Era of AI	2023	Threat Hunting	AI-based approaches for predictive threat hunting	Deep learning & anomaly detection	AI speeds up detection but false positives remain an issue
[19]	Dark Web Marketplaces & Ransomware Operations	2021	Dark Web Monitoring	How ransomware groups operate in dark web	Case study & forensic analysis	High risk of misinformation & operational secrecy
[20]	Cyber Threat Intelligence Fusion Techniques	2022	CTI Integration	Methods for integrating multiple CTI sources	Big data analytics	Reduces intelligence gaps but requires data normalization
[21]	Adversarial AI in Threat Intelligence	2023	Automated CTI	How attackers bypass AI-based CTI	AI model adversarial attacks	AI needs better adversarial robustness
[22]	Comparative Study of Threat Intelligence Platforms	2020	Automated CTI	Benchmarking different CTI platforms	Experimental study	Commercial tools vary in effectiveness
[23]	Behavioral Analytics for Proactive Threat Detection	2022	Threat Hunting	User behavior analytics for insider threats	Machine learning & anomaly detection	High accuracy but privacy concerns exist
[24]	Enhancing SOC Efficiency with AI-Powered CTI	2023	CTI & SOC	AI-driven automation in SOC workflows	Security orchestration	Faster response but reliance on AI explanations

[25]	Predictive Threat Intelligence: Forecasting Cyber Threats	2023	Automated CTI	AI-powered predictive analytics for cyber threats	ML forecasting models	Helps proactive security but limited real-world testing

Key Insights from the Comparative Table

- **Automated Threat Intelligence Platforms (Papers 1, 4, 6, 12, 21, 22, 25)**
  - AI and machine learning are improving real-time threat intelligence, but false positives and adversarial AI attacks remain major challenges.
  - SOAR and automated SOC solutions (Paper 15, 24) improve response efficiency, but they require human oversight.
  - Predictive analytics (Paper 25) shows promise but needs better real-world validation.

- **Dark Web Monitoring (Papers 2, 7, 13, 16, 19)**
  - Blockchain analytics and NLP (Papers 2, 7, 16) improve dark web monitoring, but privacy concerns remain.
  - Law enforcement use of dark web data (Paper 16) faces legal challenges in cross-border intelligence sharing.
  - Graph-based analysis of ransomware groups (Paper 19) reveals deep connections between dark web forums and cybercrime networks.

- **Threat Hunting (Papers 3, 8, 9, 18, 23)**
  - AI-enhanced threat hunting (Papers 3, 18, 23) speeds up detection, but human analysts are still needed.
  - SIEM-based threat hunting (Paper 9) improves real-time monitoring but lacks predictive capabilities.

- **CTI Integration & Future Directions (Papers 5, 10, 14, 17, 20)**
  - Federated Learning and Blockchain-based CTI Sharing (Papers 5, 10, 20) improve privacy but require more adoption.
  - Zero Trust-based CTI (Paper 17) enhances network security but increases complexity and cost.

IV. CONCLUSION

Cyber Threat Intelligence (CTI) plays a crucial role in modern cybersecurity by enabling proactive threat detection and mitigation through Automated Threat Intelligence Platforms, Dark Web Monitoring, and Threat Hunting. Automated CTI platforms leverage AI and machine learning to enhance real-time threat detection, yet challenges such as false positives, adversarial AI attacks, and human oversight remain significant concerns. Dark Web Monitoring provides critical intelligence on cybercriminal activities, but ethical, privacy, and legal issues hinder its full potential. Threat Hunting has evolved from reactive to proactive methodologies using behavioral analytics and anomaly detection, though resource demands and talent shortages limit widespread adoption. The integration of these CTI components is essential for a holistic cybersecurity strategy; however, challenges like standardization, interoperability, and data silos hinder seamless collaboration. Future research should focus on enhancing AI-driven automation with explainable AI, developing secure threat intelligence-sharing models using blockchain and federated learning, improving ethical dark web intelligence frameworks, and fostering human-AI collaboration in threat hunting. Standardized frameworks for CTI platforms will also enhance real-time intelligence sharing and detection capabilities. As cyber threats grow increasingly sophisticated, a balanced approach where automation supports human expertise will be key to building a resilient and adaptive cybersecurity ecosystem capable of countering evolving cyber threats effectively.

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Privacy-Preserving AI in Agriculture: A Review of Federated Learning Approaches

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Abstract: Federated Machine Learning (FML) is a revolutionary approach for training machine learning models while ensuring data privacy and security. This paper provides a comprehensive analysis of FML and its applications in agriculture. We examine how FML enhances predictive analytics, fosters collaborative learning among agricultural stakeholders, and addresses challenges such as communication constraints and data heterogeneity. Additionally, we explore real-world implementations and present relevant datasets that highlight the impact of FML on modern agricultural practices.

Keywords: Federated Learning, Machine Learning Agriculture, Precision Agriculture, Smart Farming, IoT in Agriculture, Crop Monitoring

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I. INTRODUCTION

1. Digital Transformation in Agriculture

Digital transformation of agriculture is being accelerated through technological innovations that support productivity, sustainability, and resource use. Emerging technologies including Machine Learning (ML), the Internet of Things (IoT), and remote sensing are at the heart of the transformation of modern agriculture - allowing for real-time monitoring, predictive analytics, and informed decisions about data-driven practices in agriculture to improve production functions, such as optimizing crop yields; improving soil and land quality; and managing water resources[1]. Machine learning is particularly important in precision agriculture by utilizing data collected from ground-based sensors, drones, and satellite imagery to identify patterns, predict pathogenic diseases, optimize fertilizer use, and utilize a data-driven supply chain management approach. While there is much promise in utilizing machine learning in agriculture, a number of barriers still exist for large-scale adoption of machine learning is agriculture[2].

2. Challenges in Machine Learning Adoption in Agriculture

- While machine learning (ML) has illustrated potential applications in the agricultural domain, there are numerous important barriers to its integration [3]:
- **Fragmentation of data:** Agricultural data is largely dispersed across different entities (e.g., individual farmers, cooperatives, government agencies, research institutions), and the absence of a shared data platform or system makes it impractical to design useable ML models that can be generalized across crop types and agronomic regions.

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- **Privacy:** Agricultural professionals and agribusinesses are often reluctant to share their data due to privacy and competitive concerns. Standard practice in machine learning is for models to require a centralized data system for storage and the use of this data which raises additional privacy and security challenges and limits involvement of multiple groups to share the data or the storage of data.

- **Expensive centralized processing and storage**: Building machine learning models typically require a considerable number of computational resources to store and process data. The cost of storing and processing vast amounts of data could be prohibitive for smaller to medium size farms to invest in cloud services or other high-performance computing investing services.

3. Federated Machine Learning: A Decentralized Solution

To address these difficulties, Federated Machine Learning (FML) has arisen as a decentralized alternative to traditional machine learning. FML enables various organizations to collaborate in the training of machine learning models without needing to exchange raw data[4]. Instead of sending data to a central repository, it enables local devices—such as farm sensors, edge devices, or regional data centers—to train models independently and provide only model updates to a central aggregator. This method preserves data privacy, minimizes communication costs, and facilitates collaboration among diverse stakeholders[2].

3.1 Fundamental Principles of Federated Machine Learning

FML is based on these principles:

1. Training locally: All data stays on local devices containing the specific model, and that device performs the machine learning training at the edge.

2. Model combining: Rather than send all the data used for training, the only things sent to the global model are any model changes (e.g., weight changes).

3. Protecting privacy: Because you are not sending the raw data, the risk associated with data security is reduced and privacy protection is increased.

4. **Decentralized collaboration:** Different entities (such as farmers, agribusinesses, and research organizations) can share data and train models together without actually seeing each other's private data.

These principles enable FML to be a scalable and privacy-protected approach to meeting the demands of the new data-driven agricultural production paradigm[5].

4. Applications of FML in Agriculture

FML can transform various aspects of agriculture by giving data-driven insights without compromising data privacy. Major applications are[6]:

4.1 Detection of Crop Diseases

Centralized data gathering for traditional ML models might be difficult for small farmers. FML enables individual farmers to train localized models for disease detection while feeding a global model with improved accuracy without compromising data privacy.

4.2 Yield Prediction

Accurate yield prediction is necessary for supply chain planning and efficient allocation of resources. FML allows farms to share work in developing training models for yield prediction based on local weather, soil type, and past yields.

4.3 Soil Health Monitoring

By combining information from soil sensors on various farms, FML can improve soil health evaluations while keeping data ownership at the farm level. This optimizes fertilizer application and minimizes environmental impact.

4.4 Smart Irrigation Systems

FML can amplify smart irrigation by aggregating localized information from various farms to enhance water management practices. This can be beneficial in water-scarce areas, where optimized irrigation will result in meaningful savings in water use.

4.5 Livestock Health Management

With the use of IoT devices and wearables, livestock health information can be processed using FML models to achieve early disease identification and optimal herd management with guaranteed data security.

Federated Machine Learning provides an innovative platform for agriculture, supporting collaborative model training while maintaining data security. With the solution to problems like data fragmentation, privacy, and computation costs, FML facilitates scalable and efficient AI-powered solutions in agriculture. Future research can emphasize how to enhance the efficiency of communication in FML, increase model resistance to adversarial attacks, and extend its applicability to other agricultural fields.

II. RESEARCH METHODOLOGY

The research takes a systematic and comprehensive approach to investigate the use of Federated Machine Learning (FML) in agricultural science. The procedures adopted are meant to provide literature that is relevant, updated, and of high quality. The steps undertaken are database selection, search strategy, inclusion/exclusion criteria, screening, quality assessment, data extraction, synthesis, and the final selection of literature, each to be outlined below[7].

1. Database Selection

To identify relevant literature, the following academic databases and digital libraries were utilized due to their comprehensive coverage of computer science, agriculture, and interdisciplinary research:

- Google Scholar
- IEEE Xplore
- PubMed
- SpringerLink
- ScienceDirect
- ACM Digital Library
- arXiv
- Web of Science

These platforms were chosen for their extensive repositories of peer-reviewed journal articles, conference papers, and preprints, ensuring a broad and diverse collection of studies.

2. Search Strategy

A systematic search strategy was employed to identify studies related to Federated Machine Learning and its applications in agriculture. The search terms were categorized into two groups:

- **Federated Machine Learning Terms**: "Federated Learning," "Decentralized Machine Learning," "Privacy-Preserving Machine Learning," "Collaborative Learning."
- **Agriculture Terms**: "Precision Agriculture," "Crop Monitoring," "Yield Prediction," "Livestock Management," "Climate Resilience," "Agricultural IoT."

Boolean operators (AND, OR) were utilized to combine these terms. Examples of search queries include:

- ("Federated Learning" OR "Decentralized Machine Learning") AND ("Precision Agriculture" OR "Crop Monitoring")
- ("Federated Learning") AND ("Livestock Management" OR "Climate Resilience")

The investigation focused on articles from peer-reviewed journals, conference proceedings, and preprints released between 2016, when FML began, and 2024.

3. Inclusion and Exclusion Criteria

In order to ensure that studies included were relevant and written to a certain quality, we included studies according to the following criteria:

Inclusion Criteria

- FML Relevance: The studies should explicitly include Federated Machine Learning or variants of such methods.
- Use in Agriculture: The studies should show an application of Federated Machine Learning methods in agriculture or agricultural-related domains, for example, precision agriculture, crop monitoring, livestock management, or climate adaptability.
- Peer-Reviewed Studies: Only peer-reviewed journal articles, conferences, and reputable sources of preprint materials (e.g., arXiv) were covered.
- Sufficient Technical Details: the studies should provide enough technical depth on the FML framework, algorithms, or implementation.
- Most Recent Studies: The researchers placed preference on studies that had been published in the last 5 years ((2019-2024) in order to stay as current with the most recent advancements in the field.

Exclusion Criteria

- Irrelevant: Studies that did not explicitly focus on Federated Machine Learning (or an unnamed variant) applied to agriculture were ruled out from the inclusions.
- No Technical Detail: Studies that were purely conceptual or simply lacked technical depth were ruled out.
- Duplicating Studies: Complete duplications of studies, or papers with significant duplication were ruled out.

- Outdated Studies: Studies that had been published before 2016, unless they were considered foundational were ruled out.

4. Screening Process

The review process was divided into two stages: -

Phase one: Title and Abstract Review: All studies identified were screened on their titles and abstracts for relevance according to the inclusion and exclusion criteria, and excluded if they were clearly not applicable.

Phase two: Full-Text Review: The full text of the remaining studies was evaluated for consideration of relevance, technical rigour, and suitability to the research purpose. Those studies that met all inclusion requirements were selected for full review.

5. Quality Assessment

To ensure the reliability and validity of the selected studies, a quality assessment was performed based on the following criteria:

- **Methodological Rigor**: The study should employ a robust methodology for implementing and evaluating FML.
- **Reproducibility**: The study should provide sufficient details for reproducibility, such as datasets, algorithms, and evaluation metrics.
- **Impact and Citations**: Preference was given to studies with high citation counts or those published in high-impact journals/conferences.
- **Novelty**: The study should contribute novel insights or advancements to the field of FML or its applications in agriculture.

6. Data Extraction

For each selected study, the following data was extracted:

- Authors and Publication Year
- Title and Source
- Key Objectives
- FML Framework and Algorithms
- Application in Agriculture
- Key Findings and Contributions
- Limitations and Future Directions

7. Synthesis and Analysis
The extracted data was analyzed to identify recurring themes, emerging trends, and gaps in the existing literature. The findings were organized into sections such as principles of FML, applications in agriculture, advantages, challenges, and future directions.

8. Final Selection
After the screening, quality assessment, and data extraction, a final set of studies was selected for inclusion in the review.

III. LITERATURE REVIEW

Federated Machine Learning (FML) has revolutionized agriculture with its decentralized, privacy-enhancing, and collaborative data analysis. The current developments in FML applications in agriculture are discussed in this section with an emphasis on precision farming, crop monitoring, livestock management, and climate resilience. Summary in a tabular structure is presented below:

TABLE I:
LITERATURE REVIEW SUMMARY

Year	Title	Authors	Summary
2024	Exploring Machine Learning Models for Federated Learning: A Review of Approaches, Performance, and Limitations[8]	Elaheh Jafarigol, Theodore B. Trafalis, Talayeh Razzaghi & Mona Zamankhani	Surveys ML algorithms (supervised/unsupervised, reinforcement learning) in FL contexts. Privacy-preserving ML techniques, blockchain integration, crisis management applications.
2021	The Role of Cross-Silo Federated Learning in Facilitating Data Sharing in the Agri-Food Sector[9]	Aiden Durrant, Milan Markovic, David Matthews, David May, Jessica Enright, Georgios Leontidis	This research presents a federated learning method aimed at improving data sharing in supply chains while avoiding the exchange of raw data, with an emphasis on predicting soybean yields. The results demonstrate improved model performance through decentralized data utilization[10].
2024	Federated Learning in Food Research[11]	Zuzanna Fendor, Bas H. M. van der Velden, Xinxin Wang, Andrea Jr. Carnoli, Osman Mutlu, Ali Hurriyetoglu	This systematic review examines the use of federated learning within the food sector, addressing topics like the evaluation of water and milk quality, cybersecurity for water treatment, analysis of pesticide residue risks, and identification of weeds. It emphasizes the prevailing concentration on centralized horizontal federated learning while pointing out deficiencies in vertical or transfer federated learning and decentralized frameworks.
2023	Model Pruning Enables Localized and Efficient Federated Learning for Yield Forecasting and Data Sharing[12]	Andy Li, Milan Markovic, Peter Edwards, Georgios Leontidis	The paper introduces a method combining model pruning with federated learning to address data heterogeneity and communication efficiency in agriculture. Experiments with soybean yield forecasting show improved inference performance and reduced model sizes and communication costs[13].
2023	Federated Learning: Crop Classification in a Smart Farm Decentralised Network[14]	Godwin Idoje, TasosDagiuklas, Muddesar Iqbal	The research explores how federated learning can be utilized in smart agriculture, specifically for classifying crops based on climatic factors. It assesses the performance of decentralized models against centralized ones, revealing that decentralized models reach convergence more quickly and provide greater accuracy.
2024	Federated Learning Architectures: A Performance Evaluation with Crop Yield Prediction Application[15]	Anwesha Mukherjee, Rajkumar Buyya	This study applies both centralized and decentralized federated learning models to predict crop yields utilizing Long Short-Term Memory Networks. It assesses the performance based on prediction accuracy, precision, recall, F1-Score, and training

			duration, showing improved prediction accuracy and shorter response times compared to conventional cloud-based methods.
2024	Crop Irrigation Advisory System Using Federated Logistic Regression[16]	Deepthi Gardas, R. Karthi	The study develops a federated irrigation advisory system using logistic regression to predict irrigation needs based on field parameters. It employs a client-server architecture with the Flower framework and evaluates the model's performance, discussing factors affecting federated learning in agricultural applications.

The studies examined evidence of growing influence and adoption of Federated Machine Learning in agriculture, due in part to its possibilities for addressing data privacy, scalability, and collaboration issues. There are several notables' uses of FML in agriculture including precision farming, crop surveillance and monitoring, animal husbandry and livestock management, and climate resilience. Smart farming technologies consisting of FML are increasingly prevalent in agricultural applications despite recognized limitations and barriers associated with their use, such as communication overhead, heterogeneous models, and data imbalance. Future research should incorporate optimization and applicability of FML systems in agricultural settings, and also consider adoption and integration possibilities with emergent technologies, such as blockchain or edge computing.

This review identifies FML based system as a considerable opportunity for innovating current agricultural practices while supporting concerns associated with data privacy and supervision, and emphasizing greater collaboration between agricultural stakeholders.

IV. PRINCIPLES OF FEDERATED MACHINE LEARNING

Federated Machine Learning (FML) is a collaborative framework of training models in a decentralized manner so that multiple participants can collectively train a machine learning model without revealing their original data. FML methodology provides data privacy and security and utilizes distributed computational power. The core principles of FML are[17]:

1. **Decentralized Model Training**: In contrast to conventional centralized ML models, FML enables edge devices or local servers to independently train models on their own datasets and share only the model updates[4].
2. **Privacy Preservation**: As raw data stays at the origin, FML complies with privacy laws like GDPR and HIPAA, rendering it appropriate for delicate sectors such as healthcare and agriculture[18].
3. **Model Aggregation**: A main server combines local model updates through methods like Federated Averaging (FedAvg) or Federated Proximal (FedProx), guaranteeing an enhanced global model[18].
4. **Data Heterogeneity Management**: FML handles non-IID (Independent and Identically Distributed) data from various devices by employing sophisticated optimization and regularization methods[18].
5. **Efficient Communication**: FML reduces bandwidth consumption by only transmitting model parameters instead of entire datasets, making it feasible for resource-constrained environments like remote farms[4].
6. **Robustness and Security**: Methods like differential privacy, secure aggregation, and homomorphic encryption reduce risks associated with data breaches, model inversion attacks, and adversarial manipulations[4].

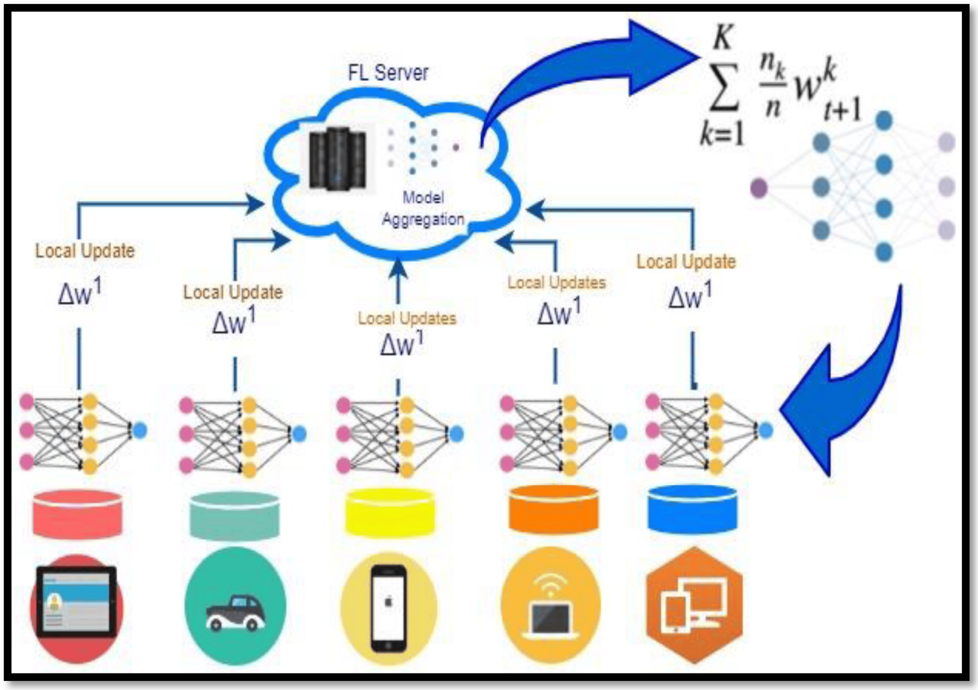

Fig.1 Federated learning methodology for an iterative process [19]

V. ADVANTAGES OF FEDERATED MACHINE LEARNING IN AGRICULTURE

Advantages

1. Privacy and Security

- FML eliminates the need for data centralization, reducing the risk of data breaches and ensuring compliance with privacy laws[4].
- Secure aggregation techniques ensure that individual contributions remain anonymous.

2. Scalability and Efficiency

- FML allows large-scale collaboration between farms, agricultural research institutions, and agritech firms without requiring massive centralized infrastructure.
- It reduces data transfer costs, making it suitable for real-time applications like pest identification and crop yield prediction.

3. Handling Data Heterogeneity

- Traditional ML models struggle with variations in climate, soil, and farming practices across different locations. FML enables region-specific training while maintaining a globally optimized model.
- It accommodates non-uniform data distribution across different farms, ensuring more representative and generalizable predictions.

4. Improved Model Performance

- FML enhances the accuracy of agricultural ML models by incorporating diverse datasets from multiple locations while mitigating biases associated with limited data sources.
- Domain-specific adaptations, such as federated pruning or transfer learning, improve inference speed and reduce computational demands.

5. Cost-Effectiveness

- Eliminates the need for expensive cloud-based data processing and storage.
- Enables low-power edge computing on IoT devices, drones, and farm sensors, reducing dependency on high-end infrastructure.

Disadvantages

1. High Communication Overhead

- Secure raw data transmission is compromised, but iterative model updating involves several communication rounds between the local devices and the aggregator, with latency.

- The resource-constrained environment will have issues with flaky network connectivity, resulting in inconsistency in FML training.

2. Model Aggregation Complexity

- Model inconsistency can be induced by aggregating updates from extremely heterogeneous datasets and must be tackled with some aggregation methods.
- System heterogeneity (e.g., variation in the capabilities of devices) is another problem to be encountered.

3. Vulnerability to Security Threats

- FML is vulnerable to attacks from attackers, i.e., exposures to poisoning attacks, where malicious nodes provide erroneous updates to poison the global model.
- Secure Multi-Party Computation (SMPC) and Differential Privacy (DP) involve computational overhead, impacting the efficiency of the model.

4. Limited Availability of Standardized Datasets

- As compared to classical ML, which has well-curated centralized datasets, FML lacks any standard datasets and therefore is restrictive for benchmarking.

- Variation in model performance can be attributed to differences in data collection techniques between different agricultural stakeholders.

VI. CONCLUSION

Federated Machine Learning presents a revolutionary approach to combining AI and ML for agriculture to support collective learning and data privacy[4]. Precision farming and livestock production to climate resilience and supply chain optimization are some of the key challenges of modern farming solved by FML. The literature presents great contributions toward yield estimation, pest detection, soil monitoring, and irrigation scheduling using FML-based models.

However, the high communication cost, security attacks, and data heterogeneity are still challenges. Further research on efficient aggregation algorithms, privacy-preserving techniques, and real-time FML deployments will be important to realizing its full potential. Regardless of the future challenges, FML will be a foundation of AI-based agriculture, enabling sustainable, data-driven, and smart agricultural practice.

VII. FUTURE DIRECTIONS

1. **Optimized Communication Strategies**
   Research should focus on reducing communication overhead using compression techniques, such as sparsification and quantization, to make FML viable for real-time agricultural applications.

2. **Privacy-Enhancing Technologies**
   Integrating advanced privacy mechanisms like secure federated learning (SFL), differential privacy, and blockchain-based FML can enhance trust and security in agricultural collaborations.

3. **Federated Transfer Learning**
   Integrating FML with transfer learning can mitigate data heterogeneity by enabling pre-trained models to be fine-tuned for specific agricultural regions or crop types.

4. **Edge Computing and IoT Integration**
   Future studies should explore deploying FML on IoT-enabled edge devices such as smart tractors, drones, and greenhouse sensors to enable localized and low-latency decision-making.

5. **Adaptive Aggregation Methods**
   Developing dynamic aggregation techniques that account for varying farm conditions and resource constraints will improve the reliability and accuracy of federated models.

6. **Real-World Deployment and Benchmarking**
   There is a need for standardized agricultural FML datasets and real-world pilot programs to validate the effectiveness of proposed frameworks in diverse farming conditions.

7. **Multi-Modal Data Fusion**
   Future FML applications should incorporate diverse data sources, such as satellite imagery, weather forecasts, and soil sensors, to develop robust predictive models for sustainable agriculture[20]

By addressing these challenges and leveraging advancements in AI and ML, FML has the potential to revolutionize digital agriculture, making farming more efficient, productive, and environmentally sustainable.

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Precision Agriculture Reimagined: A Review on the Role of Semiconductors and AI in Smart Farming 2.0

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Abstract: Smart Farming 2.0 is an evolution of traditional precision farming that utilizes both semiconductor technologies and artificial intelligence (AI) for increased productivity, sustainability, and efficiency in farming practices. This review provides a thorough overview of the latest developments in both semiconductors and AI uses within today's agriculture. It will thoroughly cover the use of sensors, embedded devices, and edge devices along with AI models such as machine learning and deep learning in decision-making on the farm. An extensive review of the literature is included to help frame existing work within possible combinations of systems and future options, providing the knowledge needed for researchers, practitioners, and policymakers who are rethinking agriculture through intelligent farming.

Keywords: Smart Farming 2.0, Precision Agriculture, Semiconductors in Agriculture, Artificial Intelligence, Edge Computing, IoT in Farming, Agricultural Sensors, Machine Learning, Agricultural Robotics, Decision Support Systems

I. INTRODUCTION

The evolution of agriculture from traditional farming to data-driven, precision farming represents a major technology migration. Precision agriculture focuses on field-level management of crop production and livestock and incorporates new methods of optimizing the use of agricultural inputs. With smart devices and allied semiconductor technology coupled with AI tools, precision agriculture has now merged into Smart Farming 2.0, which allows farmers to get real-time data, monitor use of resources, and even automate certain activities to enhance yield and sustainability. This paper aims to systematically review the key technologies driving this migration to smart farming, examine examples of state-of-the-art applications that utilize these technologies, and outline future possibilities for advanced technologies in agriculture. According to the Food and Agriculture Organization (FAO), approximately 70% increase in food production globally will be necessary to feed a growing world population by 2050[1]. Conventional farming methods are characteristically resource-intensive, using significant quantities of water, fertilizer, and human labour. Yet, as a result of semiconductor-based AI advancements, efforts to reduce these inherent inefficiencies are underway, allowing for the implementation of precision farming, automation, and data to inform decision making[2].

Sensors based on semiconductors play a critical role in modern agriculture by providing data on crop status, soil conditions, and climatic conditions. With the use of AI algorithms, sensors support predictive analytics and improve the efficacy of agricultural inputs to address sustainability concerns and improve yields[3]. The work of IoT devices has enabled real-time monitoring of farming activities and management remotely. This advancement was made possible by advances in semiconductor technology[4]. Besides precision farming, autonomous equipment is also transforming the agriculture industry. Advanced semiconductor processors are being integrated into AI-powered robots and drones to perform tasks such as planting, weeding, and harvesting[5]. The technologies not only save labor costs but also enhance operational efficiency and accuracy. In addition, edge AI computing is facilitating quick decision-making by processing

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data for agriculture locally as opposed to the use of cloud-based processing, minimizing latency and improving data protection[6].This paper considers recent progress, challenges, and market forces connected with AI-backed semiconductor innovation in agriculture. Examining the place of semiconductor innovations in meeting most important agricultural concerns, we want to provide perception into their power to increase sustainability and productivity for contemporary agriculture.

II. TRENDS IN SEMICONDUCTOR INNOVATIONS FOR AGRICULTURAL AI

2.1 Role of Semiconductors in Precision Agriculture

Semiconductors at the core of smart farming tools enable sensors, microcontrollers and connectivity systems.

- Sensing: Semiconductor chips are used in soil moisture, temperature, and nutrient sensors for accuracy and portability.
- Connectivity: IoT devices use semiconductor-based wireless modules (such as LoRa and ZigBee) to send data.
- Processing: Edge computing powered by microprocessors reduces the latency of data analysis.
- Low-power semiconductors for energy-efficient devices, which are particularly useful in remote farming locale[7].

2.2 AI's function in precision farming

AI drives automation and optimization by converting unprocessed data into actionable insights[4]:

- Machine Learning (ML): Random Forests and Neural Networks are two examples of algorithms that forecast agricultural yields and identify illnesses[8].
- Computer Vision: Using drones or cameras, AI-powered imaging detects weeds, pests, and crop health.
- Decision Support Systems (DSS): AI combines market, weather, and soil data to manage farms in real time[9].

2.3 Sensor Technologies and IoT Integration

Sensors that are based on semiconductors (for example, soil moisture, nutrient and infrared sensors) enable real-time information collecting for precision farming. Internet of Things (IoT) systems utilize sensors to control irrigation systems, manage animal health and welfare, and fix environmental conditions in a greenhouse. One example of an IoT sensor is a solar-powered sensor that decreases water consumption by 70 percent in a smart greenhouse. In summary, here is an organized review table that illustrates the key topics of sensor technologies and IoT integration from the search results, along with links to the relevant papers[6]:

TABLE I:
REVIEW ON SENSOR TECHNOLOGIES AND IOT INTEGRATION

Paper Title	Sensor Technology Focus	IoT Integration Application	Key Contributions
A Review on Emerging Applications of IoT and Sensor Technology for Industry 4.0 [10].	IoT sensors, edge computing, 5G	Industry 4.0, smart warehouses, inventory management	Discusses advancements in IoT-enabled Industry 4.0, challenges (security, privacy), and trends like edge computing and 5G networks. Highlights smart warehouse architectures and railway IoT systems.
IoT Sensing Applications Using RFID and WSN [11]	RFID sensors, wearable devices	Wearable tech, supply chain management	Analyzes analog/digital RFID sensing, energy harvesting challenges, and anti-collision protocols. Explores hybrid RFID-WSN integration for long-range monitoring.
Challenges, Applications, and Future of Wireless Sensors in IoT[12].	Wireless sensor networks (WSNs)	Environmental monitoring, industrial automation	Reviews security challenges (e.g., eavesdropping, jamming) and proposes machine learning solutions for IoT-integrated WSNs. Explores scalability and energy efficiency in industrial IoT.
Internet of Things:	Multi-layer IoT	Smart cities,	Proposes a generic IoT architecture, discusses

Architectures, Challenges, and Applications[13]	architectures	transportation, energy	market opportunities, and highlights challenges in scalability and data management. Covers applications in traffic monitoring and healthcare.
Smart Sensors: Analysis of Different Types of IoT Sensors[14]	RFID, pressure, temperature, motion sensors	Healthcare, agriculture, smart cities	Classifies IoT sensor types and their applications. Emphasizes RFID integration for real-time data collection and challenges in sensor interoperability.
Security Challenges in Wireless Sensor Networks for IoT[15]	WSNs, intrusion detection systems	Critical infrastructure, healthcare	Identifies security vulnerabilities (e.g., spoofing, node replication) and proposes blockchain and machine learning-based mitigation strategies.

2.4. AI-Driven Analytics and Edge Computing

AI algorithms process sensor data to predict crop yields, detect pests, and simulate climate scenarios. Edge AI reduces latency by processing data locally on farms, enhancing decision-making speed. Innovations like MEMS (Micro-Electro-Mechanical Systems) enable low-cost, scalable soil monitoring solutions[16].

TABLE II:
REVIEW ON AI-DRIVEN ANALYTICS AND EDGE COMPUTING

Paper Title	Technology Focus	Application	Key Contributions
AI-based Fog and Edge Computing: A Systematic Review, Taxonomy and Future Directions[17]	AI in 'Fog' and 'Edge' Computing	Smart cities, healthcare, IoT	Systematic review, taxonomy of AI models, future research directions.
AI Augmented Edge and Fog Computing: Trends and Challenges[18]	Federated Learning, Edge AI Optimization	Industrial automation, real-time decision-making	Discusses AI-driven optimizations, federated learning, emerging challenges.
Edge Intelligence: Paving the Last Mile of AI with Edge Computing[19]	Edge Intelligence	IoT, Smart Healthcare, Intelligent Transportation	Defines "Edge Intelligence," classifies approaches, and explores future research gaps.
Edge Intelligence: The Confluence of Edge Computing and AI[20]	AI-Edge Integration, Reinforcement Learning	Robotics, Autonomous Vehicles	Surveys AI techniques for edge computing, focusing on reinforcement learning and deep learning.
AI on the Edge: A Comprehensive Review[21]	AI Deployment on Edge Devices	Real-time AI Applications, AI Hardware	Discusses AI model deployment strategies, hardware constraints, and real-world applications.

2.5 Generative AI for Predictive Modeling

By augmenting productivity, optimization of resources, and better decision-making, machine learning (ML), deep learning (DL), artificial intelligence (AI), and conversational AI models such as ChatGPT are revolutionizing the agricultural sector. Some key issues such as surveillance agriculture, pest monitoring, weather forecast, and evaluation of soil are being resolved using these technologies. DL-based image processing aids in real-time monitoring of crop and animals in precision agriculture while AI-based prediction models optimize the planting calendar and prevent outbreaks of diseases. ChatGPT and other AI conversational systems offer real-time advisory services that simplify processes such as market research and supply chain management. Future innovation is likely to involve the infusion of AI with IoT, the use of edge computing to make decisions locally, and the use of blockchain for supply chain transparency[22].

TABLE III:
REVIEW ON GENERATIVE AI FOR PREDICTIVE MODELING

Paper Title	Technology Focus	Application	Key Contributions
Application of Machine Learning in Agriculture: Recent Trends and Future Research Avenues[23]	Machine Learning (ML), Deep Learning (DL)	Crop yield prediction, soil quality analysis	Offers a detailed summary of ML and DL applications in agriculture, highlights research gaps, and proposes future research directions for enhanced agricultural outcomes.
Generative Adversarial Networks for Image Augmentation in Agriculture: A Systematic Review[24]	Generative Adversarial Networks (GANs)	Crop disease detection, remote sensing	Examines the role of GANs in enhancing agricultural datasets, improving the precision of predictive models for disease detection and remote monitoring.
Revolutionizing Agrifood Systems with Artificial Intelligence: A Survey[25]	AI, Generative AI, Predictive Analytics	Smart farming, precision agriculture	Explores AI's impact on improving food production efficiency, minimizing waste, and promoting sustainable practices in agrifood systems.
A Comprehensive Modeling Approach for Crop Yield Forecasts using AI-based Methods and Crop Simulation Models[26]	AI-based Crop Simulation, ML Models	Crop yield forecasting, climate impact analysis	Integrates AI techniques with conventional crop simulation models to achieve more accurate yield forecasts under varying climatic conditions.
Generative AI in Smart Agriculture: Opportunities and Challenges[27]	Generative AI, Neural Networks	Automated pest detection, soil moisture monitoring	Discusses how generative AI improves data augmentation and predictive modeling for pest control and soil monitoring, while addressing implementation challenges.
Artificial Intelligence in Agriculture: A Review[28]	AI, ML, DL, IoT Integration	Smart irrigation, automated monitoring	Provides an in-depth review of AI-driven solutions in agriculture, emphasizing automation, real-time monitoring, and IoT integration for optimized farming practices.

2.6 Review on Robotics and Autonomous Systems in AI and Semiconductor Technologies

AI-powered robotics and autonomous systems heavily rely on semiconductor components for real-time data processing, navigation, and decision-making. For example, agricultural robots equipped with AI have demonstrated an 80% reduction in pesticide usage while mitigating labor shortages[29]. Below is a summary of key research papers in this domain:

TABLE IV:

REVIEW ON ROBOTICS AND AUTONOMOUS SYSTEMS IN AI AND SEMICONDUCTOR TECHNOLOGIES

Paper Title	Technology Focus	Application	Key Contributions
Security Considerations in AI-Robotics: A Survey of Current Methods, Challenges, and Opportunities[30]	Security in AI-Robotics Systems	Service Robots, Autonomous Vehicles	Analyzes potential vulnerabilities in AI-robotics systems and offers protective measures. Addresses ethical and legal issues, such as accountability and psychological effects. Examines security in Human-Robot Interaction (HRI), emphasizing privacy, data integrity, safety, trust, and transparency, while suggesting future research paths for improved security.
Artificial Intelligence for Long-Term Robot	AI Techniques	Service Robotics, Field Robotics	Explores AI strategies that allow robots to function independently over long durations in

Autonomy: A Survey[31]	for Long-Term Autonomy		dynamic settings. Covers navigation, mapping, perception, knowledge structuring, reasoning, planning, interaction, and learning. Highlights the integration of these approaches for prolonged autonomy and identifies upcoming challenges and opportunities in AI-driven robotics.
Deep Learning in Robotics: A Review of Recent Research[32]	Deep Learning Applications in Robotics	Various Robotic Systems	Investigates the application of deep learning in physical robotic systems. Evaluates the strengths and weaknesses of deep learning through recent studies. Seeks to share cutting-edge developments with the robotics field and encourage further adoption of deep learning in robotic technologies.
A Comprehensive Review on Autonomous Navigation[33]	Autonomous Navigation Systems	Mobile Robots, Autonomous Vehicles	Provides a detailed examination of autonomous mobile robots, encompassing sensor varieties, platforms, simulation tools, path-planning techniques, sensor fusion, obstacle avoidance, and simultaneous localization and mapping (SLAM). Stresses the role of deep learning in autonomous navigation and discusses future research possibilities and hurdles.
Artificial Intelligence for Robotics and Autonomous Systems Applications[34]	AI Integration in Robotics	Unmanned Vehicles, Cooperative Robots, Remote Sensing	Focuses on AI applications in robotics, particularly in processing visual and motion data. Examines the impact of machine learning, including deep learning and reinforcement learning, on robotic performance. Highlights practical uses in remote sensing and introduces emerging concepts like tiny-ML in robotics.
A Systematic Literature Review of Decision-Making and Control Systems for Autonomous and Social Robots[35]	Decision-Making and Control Architectures	Social Robots, Autonomous Assistive Devices	Reviews the evolution of decision-making and control architectures for autonomous and social robots over three decades. Identifies trends in combining biologically inspired designs with machine learning. Explores software architecture challenges for action selection and proposes directions to advance capabilities of autonomous and social robots.

III. CHALLENGES AND OPPORTUNITIES IN AGRICULTURAL AI

3.1 Technical Challenges

Technical integration of AI in agriculture has several technical challenges:

- **Heterogeneous Data Sources:** Differences in data formats (e.g., satellite imagery, IoT sensors, weather conditions) make it difficult to integrate smoothly[36].
- **Harsh Field Environments:** Robustness of hardware (e.g., drones, sensors) under extreme environmental conditions is still a challenge[37].
- R**eal-Time Processing & Power Constraints:** Constrained computation resources at the edge (e.g., on-field devices) prevent low-latency decision-making[38].

3.2 Socioeconomic Challenges

- **Digital Divide:** Rural communities typically do not have infrastructure (connectivity, power) for implementing AI-based solutions[39].
- **High Deployment Costs**: Smart farming technology (e.g., precision agriculture equipment) investment is too high for smallholders at the onset[40].
- **Training Gaps:** Stakeholders and farmers need training to adopt and have faith in data-driven decision support systems (DSS)[41].

3.3 Emerging Opportunities

- **Neuromorphic Computing:** Energy-efficient AI processors might make real-time edge processing feasible in resource-constrained environments[42].
- **Explainable AI (XAI):** Transparent models boost farmer trust in DSS by offering interpretable recommendations[43].
- **Standardized Platforms:** Open frameworks for data and tool interoperability (e.g., FAO's WaPOR) can drive adoption[44]

IV. FUTURE RESEARCH DIRECTIONS

To overcome current shortcomings, the following directions are imperative:

- **Next-Gen Connectivity:** Utilizing 6G networks and quantum computing can allow ultra-high-speed, large-volume agricultural data analytics[45].
- **Bio-Sensors**: Plant/livestock wearable devices can facilitate early disease diagnosis and animal health monitoring[46].
- **Autonomous Crop Management**: AI-based systems for end-to-end automation (planting through harvesting) via robotics and computer vision[47].
- **Blockchain for Transparency**: Secure, decentralized record-keeping to track produce from farm to consumer, ensuring compliance with sustainability[36].

V. CONCLUSION

Semiconductors and artificial intelligence constitute the pillars of Smart Farming 2.0, propelling a future of sustainable and smart agriculture. They empower accurate, timely, and data-driven farm management practices that increase efficiency and productivity. Interdisciplinary studies and investment need to continue to break existing limitations and unlock the full potential of smart farm technologies. By leveraging the capabilities of AI applications powered by semiconductors, the agricultural industry can move toward a more sustainable and robust future, guaranteeing food security for the increasing global population.

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Examining the Literature on Electric Vehicles

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Abstract: With the current depletion of fossil fuels and its rise in price there is a need to locate an alternating energy supply to run the vehicle. Given the catastrophic environmental effects of burning fossil fuels and the significant contribution of modern vehicles to pollution, electric vehicles, or E-vehicles, have emerged as a blessing for the globe. Even the recent increase in gasoline prices and the paucity of natural resources inspire people to consider e-vehicles as a great way to commute with no environmental impact. In the current global climate, green energy is essential, and the use of e-vehicles contributes significantly to the reduction of pollution. Since it is well acknowledged that e-vehicles have a vast market, it is necessary to use effective marketing strategies to raise customer awareness of the benefits of owning one and encourage them to make a purchase. It is necessary to comprehend the expectations and perceptions of the client. This article attempts to examine the body of research on the adoption of e-vehicles and to highlight consumer attitudes and intentions about e-vehicle adoption.

Keywords: E-vehicle, consumer perception, purchase intention, Environmentally Friendly

I. INTRODUCTION

The automotive sector has grown to be a significant force in both the global economy and research and development (R&D). Vehicles now have systems that put the safety of both passengers and pedestrians first thanks to the ongoing improvement of technology. As a result, there are now more cars on the road, giving us the convenience of comfortable and speedy travel. But there is a price for this advancement. Vehicles that are propelled by one or more electric motors are referred to as electric vehicles. These cars often run entirely on batteries, making them self-sufficient. We have been racing to build more electric cars ever since they first appeared in the middle of the 19th century. Efforts to reduce environmental impacts and reliance on fossil fuels are aided by electric automobiles. Electric motorcycles, electric bicycles, electric automobiles, and other vehicle types can be examples of them. In India, 90% of people and 64.4% of all commodities are transported by road thanks to a steady increase in infrastructure and improved road connections. The expansion of the Indian car industry may be explained by the rising demand for vehicles. In a country with the second-largest population in the world—nearly 130 million people, or 17.7% of the world's total population—air pollution is one of the major threats in the globe —people are having trouble breathing in the majority of the major cities. Other pollutants that autos release are source emissions and fugitive fuel; the quantity of emissions fluctuates according on the kind of vehicle, maintenance, and other variables. Due to greenhouse gas (GHG) emissions, the transportation industry contributes significantly to air pollution and climate change, mostly in metropolitan areas; This has made road transport electrified, requiring new energy cars to replace internal combustion ones. For example, electric cars appear to be a promising step in the direction of urban sustainability.

Due to the rapid expansion of the Indian car industry, electric vehicles (EVs) are emerging as a practical way to enhance economic opportunity, energy security, and air quality. The greenhouse gas problem has been getting worse every day in recent years, and the price of gasoline has increased by around 90 rupees per liter. Public transit is crucial to everyday living, yet because of the high cost of gasoline, some individuals choose not to use automobiles or bikes. In order to turn conventional vehicles into dependable electric vehicles, several automakers and startups have made an effort. An electric vehicle is one that is powered by an internal electric source and driven by electric motors. India has

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the third-largest road network in the world. For Indians, taking the street is the better option. Nearly 60% of people traveled in their own or other people's cars (Statista, 2020). Two of the main contributors to environmental air pollution and global warming are gasoline and diesel. Sixty-six percent of air pollution-related deaths in India are caused by diesel vehicles. This study has shown that India's transportation emissions, especially those from diesel, cause major health concerns. (Research by an Environmental Specialist) The Indian government has undertaken a variety of schemes to promote the development and usage of electric vehicles. As a result, EVs are now more widely available in the Indian market. The government wants to see India completely powered by electric vehicles by 2030. It has been recommended that all two-wheelers sold in the country after March 31, 2025, with engines less than 150cc, and all three-wheelers sold after March 31,

2023, be electric vehicles (EVs). (Policy for transportation) FAME India is part of the National Electric Mobility Mission Plan. FAME's primary goal is to promote electric automobiles by offering financial incentives. By giving upfront incentives for purchasing electric automobiles, FAME Schemes aim to promote the quicker adoption of Hybrid and electric automobiles. As old as the automobile it is the history of electric vehicles, or EVs. Actually, light-weight electric vehicles (EVs) were the most popular vehicle type in the United States at the beginning of the twentieth century, with the first experimental models appearing as early as the mid-1830s. However, they had fallen behind the internal combustion engine (ICE) vehicle and vanished from the market before the conclusion of World War I. Since the beginning of the twenty-first century, several nations have engaged in extensive discussions over the problems of climate change and global warming. Numerous pertinent studies have demonstrated the detrimental effects of climate change that is mostly caused by human activity. Air pollution has become a serious issue as a result of numerous enterprises using fossil fuels as a result of the world's growing industrialization and civilization (Wee, 2010). At the same time, it is impossible to overlook the exhaust emissions from automobiles. Vehicle emissions have been identified as the primary cause of the effects of greenhouse gases, contributing to the rise in many types of cancer and other severe illnesses. These emissions mostly consist of CO2, CO, NO_2, and particulate matter (PM10 and PM2.5).

II. LITERATURE REVIEW

The results and methodological and theoretical developments of the most recent research on a subject are examined in a review of the literature. The literature study makes use of secondary sources rather than the most recent or innovative experimental work. G Tamil Arasan, G Sivakumar, and Mohamed M. conducted a study on the opportunities and challenges of electric vehicles in India. Electric engines will significantly cut pollution and benefit customers when they replace internal combustion engines. Numerous nations have adopted this technology and are helping to better the environment. The study observed the potential and difficulties associated with EV implementation in India. Opportunities from industries, the environment, batteries, and government initiatives have all been taken into account. These issues were taken into account, including the demand for EVs, their cost, and their efficiency in India. The main goals of EV adoption in India are to reduce greenhouse gas emissions and oil costs. The government should take full use of the possibilities and identify appropriate solutions to the problems. (Mohamed M, 2018) Figure 1 illustrates how an electric automobile operates, with the motor receiving power from a controller that draws electricity from a battery. The electric principle powers the e-vehicle.

The electric motor is powered by a battery pack. In order to spin the transmission system, the e-motor uses the energy from the rechargeable battery. A potentiometer attached to the car's accelerator pedal tells the controller how much power should be sent to the electric motor. In order to power an electric motor that rotates the wheels, electric vehicles (EVs) store electricity in a rechargeable battery pack. A major departure from conventional gasoline-powered automobiles is represented by an electric vehicle. Fundamentally, an electric vehicle (EV) is propelled by energy that is stored in batteries as opposed to burning fossil fuels. This essential distinction changes how EVs function and makes them more environmentally friendly. Electric motors provide a greater portion of the propulsion for electric cars. These motors transform electricity into motion by drawing power from the car's battery pack. Electric vehicles (EVs) operate on the basis of converting electrical energy that is generated or stored in batteries into mechanical energy that powers the vehicle. An electric automobile is a vehicle that uses energy stored in rechargeable batteries to power its electric motors, either totally or partly.

According to Bhattacharyya and Pradhan (2023), the main contribution of this study is a summary of the challenges and problems associated with electric cars in India. The EV sector is impacted by a variety of obstacles and bottlenecks in emerging nations; some are small annoyances, while others have a big impact on growth. Social issues must be handled in addition to specialized solutions, and new difficulties are always coming up. One of the main instances that encourage companies to look for a solution to these challenges is India's highly ambitious objective of having 100% electric portability by 2030. Countries all across the world were encouraged to transition to electric vehicles by the Paris Declaration on Electro mobility.

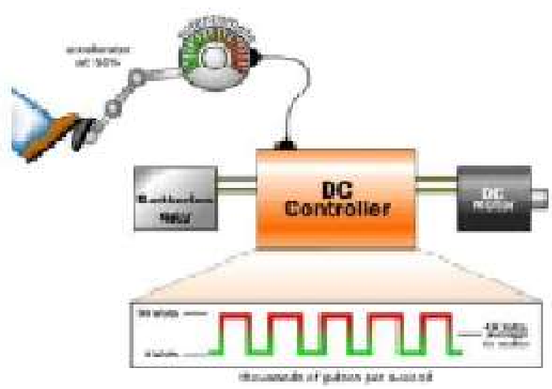

Fig. 1. Principle of Electric Car

III. EV BENEFITS

EVs can serve as a substitute mode of transportation, offering users a number of benefits, some of which are listed below:

A. Electric vehicles are environmentally beneficial.

Since EVs don't emit smoke, they don't contribute to pollution like ICE vehicles do. Thus, they aid in lowering CO2 emissions. Even when utilizing fossil fuels, EVs produce fewer pollution than cars with internal combustion engines (ICEs). Air pollution is decreased by pure EVs as they have no tailpipe emissions. Because the EV's electric motor runs on a closed circuit, it doesn't release any dangerous gasses. Since pure electric vehicles don't need gasoline or diesel, they are very environmentally friendly. EVs emit no direct emissions and have no tailpipes.

B. Low maintenance expenses.

Vehicles that run on gasoline or diesel need routine maintenance since they have a lot of moving parts. Since electric cars have fewer moving components than conventional cars, it isn't the case. This implies that the long-term maintenance costs of your electric vehicle will probably be reduced.

C. Reduced operating expenses

You save a lot of money on fuel since you don't have to pay for gasoline or diesel to keep your EV operating. When compared to the cost of gasoline or diesel, charging an electric car is far less expensive. By using sustainable energy sources like solar, you may further lower your electricity costs.

D. Reduced expenses for gasoline

Gas costs are reduced because EVs don't need gasoline. Compared to traditional cars, EVs are more efficient. EVs are less expensive per kilometer than ICE cars.

E. Zero emissions from the tailpipe

Since EVs have no exhaust emissions, they contribute to a smaller carbon impact. You may lessen your carbon footprint even further by charging your EV using renewable energy. All-electric vehicles have zero tailpipe emissions, while plug-in hybrid electric vehicles (PHEVs) likewise have no tailpipe emissions when operating in all-electric mode. The benefits of HEV emissions vary by car model and hybrid power type. The source of the electricity required to charge an electric vehicle impacts its life cycle emissions, which vary by region. In places where electricity is generated using comparably low-polluting energy sources, electric vehicles frequently outperform equivalent conventional vehicles fuelled by gasoline or diesel in terms of life cycle emissions. Nitrogen dioxide (NO2), carbon dioxide (CO2), and exhaust pollutants are not produced by these automobiles. The manufacturing processes for batteries are often more ecologically friendly, despite the fact that the creation of batteries has a negative influence on the carbon footprint compared to other manufacturing.

F. Environmentally Friendly

EVs are less polluting cars since they don't emit any exhaust. You may reduce greenhouse gas emissions even further if you choose to charge your EV with renewable energy. Some EVs are built using components that are good for the environment. For instance, old vehicle components, biobased materials, and recycled plastic bottles make up a portion of the Nissan Leaf and Ford Focus Electric.

IV. DIFFICULTIES AFFECT ELECTRIC VEHICLES (EVS)

There are still a lot of obstacles to overcome until the future of electric vehicles is established. Power generation is essential to the operation of electric vehicles in India. We cannot see the future of electric vehicles without power. Therefore, the distribution network's obligation to consistently deliver the right amount of electricity has increased.

A. Absence of infrastructure for charging

One of the biggest obstacles is the absence of a comprehensive and effective charging infrastructure. Slow charging rates, a lack of charging standards, and the expense of chargers are all potential problems for drivers. Owners of electric vehicles may worry that they could run out of fuel before arriving at their destination because these vehicles typically have a lower driving range than conventional automobiles. It is difficult to predict where electric vehicle- related technologies will go in the future because they are always undergoing development. For instance, one of the main variables influencing the adoption of EVs is battery performance, which is presently subpar. Even with recent improvements in infrastructure development, charging stations are still not as convenient or accessible as traditional gas stations.

B. Prices are expensive.

EVs can be expensive. One of the most significant barriers to the mainstream adoption of electric vehicles (EVs) is their high initial cost. The most significant impediment to the EV market is the high cost of vehicle acquisition. Because of battery technology, electric automobiles are more expensive to build than gasoline-powered vehicles. The battery is the most costly component of an electric vehicle, whose cost has been falling but is still considerable. The majority of EV batteries in India are imported from China, which raises the price.

C. Fear of the range

The restricted driving range per charge is one of the main issues causing range anxiety. EVs have always had limitations on how far they can travel on a single charge, despite tremendous advancements in battery technology. Continuous improvements in battery technology hold the key to the answer. The dread of running out of energy when operating an electric vehicle (EV) is known as range anxiety. In the past, EVs' driving range between charges has been constrained. Concerns over the vehicle's range on a single charge may arise among drivers. With a range of 370 miles between charges, The Tesla Model S currently has the greatest range of any electric vehicle on the market. In India, EVs typically have a range of 120 km when completely charged, making them unsuitable for long travels. The sluggish pace of EVs in India might put off buyers. The top two electric vehicles produced in India have top speeds of 85 km/h.

D. Battery Supply Chain and Technology

Certain minerals and rare earth elements are required to make lithium-ion batteries, which are an essential component of electric cars. India is now experiencing supply chain challenges as a result of its reliance on imported batteries for manufacturing's' convenience and usefulness are impacted by the fact that charging takes longer than refilling for traditional cars.

V. OPPORTUNITES AHEAD

The Indian government may support electric cars (EVs) in a number of ways. To promote the purchase of EVs, the government provides incentives. The government has expanded the exemption from customs duties to include the importation of capital goods and equipment used in the production of lithium-ion batteries. The government has waived road tax on EVs. The 12% GST on EVs has been lowered to 5%.The government is expanding the public charging infrastructure for EVs. The PM E-DRIVE scheme will subsidize charging stations for two- and three-wheelers. Additionally, the program requires 50% domestic value addition in chargers and gives priority to solar charging throughout the day.

VI. INDIA'S ELECTRIC VEHICLE (EV) POLICY

India's electric vehicle (EV) policy aims to promote local manufacturing and attract investments from global EV companies. In 2012, the idea for the National Electric Mobility Plan (NEMP) was developed. It was started with the goal of increasing the number of electric cars (EVs) that are purchased and used while also lowering the number of vehicles that run on fossil fuels. India's primary project to encourage electric transportation is known as FAME, or Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles. It was introduced by DHI in 2015. Presently in its second phase of execution, FAME-II is being carried out for three years, starting on April 1, 2019, with a budget of 10,000 Cr, which includes Rs 366 Cr in overflow from FAME-I. Two-wheeler: up to 40% of the vehicle's cost, or Rs 15,000 per kWh. KWh for a three-wheeler: Rs 10,000. Per kWh, four-wheeler: Rs 10,000. E-buses: 20,000 rupees per kWh. The National Electric Mobility Plan (NEMP) sought to attain 30% EV adoption in India by 2030 and sell 6–7 million EVs by 2020. In 2013, the Indian government unveiled the National Electric Mobility Mission Plan (NEMMP) 2020.By encouraging hybrid and electric cars across the nation, it seeks to achieve national fuel security. The Vehicle Scrap page Policy, This program provides incentives for the acquisition of new electric vehicles and the disposal of old vehicles. the Production Linked Incentive (PLI) program, which provides financial incentives for manufacturing electric vehicles and their components. Raising awareness of the advantages of EVs and EV charging infrastructure is the goal of the Go Electric campaign. The Ministry of Power's most recent suggestions for charging infrastructure (MoP recommendations), there should be a minimum of one charging station on either side of the highway, spaced three kilometers apart and at intervals of twenty-five kilometers. The National Mission on Transformative Mobility and Battery Storage seeks to promote the development of giga-scale battery manufacturing facilities in India. and develop a comprehensive ecosystem for EV adoption. Furthermore, the Ministry of Housing and Urban Affairs amended the Model Building Bye-laws, 2016 (MBBL) to mandate that 20% of parking spots in residential and commercial buildings be set aside for EV charging stations.

VII. LITHIUM RESERVES IN INDIA COULD REVOLUTIONIZE THE (EV)

India currently imports all of its lithium, cobalt, and nickel. Discovering lithium reserves in India could reduce the countries reduce the price of EV batteries and reduce reliance on imports. Lowering the cost of EV batteries could make EVs more affordable for Indian consumers. The lithium reserves could transform India from being just an EV consumer market to a global supplier. The reserves were found in a small area of land in the Mandya district, about 100 kilometers from Bengaluru. The reserves were estimated to be 14,100 tones of lithium metal Researchers from the Atomic Minerals Directorate, a part of India's Atomic Energy Commission, estimated that lithium resources in a small area of land surveyed in the Southern Karnataka district totaled 14,100 tones. Batteries for electric vehicles are largely made of lithium. With 9.3 million metric tons, Chile has the world's largest lithium deposits. About 33 percent of the world's lithium resource base is found in the country's Salar de Atacama, which is said to contain the majority of the world's "economically extractable" lithium deposits.

VIII. FINAL SUMMARY

One of the factors deterring consumers from buying EVs is their high cost. After I've presented all of the facts, I'll be able to make some conclusions. As technology develops, electric cars are becoming more and more viable for long-distance driving. Numerous high-end electric cars, such the Tesla Model S and Tata, are able to travel great distances while on home electricity. In addition to being able to travel great distances, these premium electric cars also save petrol costs and support environmentally friendly transportation. However, the high price of these cars may be out of reach for the majority of working-class families. However, everyone will ultimately accept electric vehicles since they are good for the environment and society. In order to address this, the government has promoted a broader adoption of EVs by offering incentives for corporate automobiles. However, foreign batteries are the fundamental reason why electric vehicles remain at least 30% more expensive.

The initial phase of the FAME program was initiated in 2015,to promote the adoption of hybrid and electric vehicles in India. It supported 2.8 lakh vehicles. In 2019, the FAME scheme's second phase was introduced to encourage the electrification of shared and public transportation. Electric two-wheelers, electric buses, electric three-wheelers, and electric four-wheeler passenger automobiles were among the electric and hybrid vehicles for which it offered incentives. Infrastructure for charging was also funded by it. The FAME program seeks to decrease vehicle emissions and lessen reliance on fossil fuels. Additionally, it backs legislative efforts including lowering the GST on EVs and facilitating state EV regulations. Over the last quarter, manufacturers have produced various new EV models that provide a higher range—some considerably more than the 80-90 km a EV delivers presently. Over 1.7 million EVs were sold in India annually in FY2025. Electric two-wheelers (E2W) accounted for almost 55% of these sales. By 2030, Deloitte projects that 31.1 million EVs will be sold annually worldwide, with 81% of those sales coming from BEVs. In India, EV sales are predicted to touch 1.644 million units by FY25 and increase to 15.331 million units by 2030. Tata Motors' Nexon EV and Altroz EV, as well as Maruti Suzuki's Futuro-e, are two EVs that have captured Everyone's curiosity in the expo. With the Ora R1, Great Wall Motors of China stole the spotlight. Another significant challenge for EVs in India is poor charging infrastructure. India's charging infrastructure requires rapid attention, since there are just 2,636 charging stations.

As stated by Rishabh Jain, manager of the public policy think tank CEEW, Centre for Energy Finance, India has plenty of energy producing capacity to power this vehicle. According to analysis, In 2017–18, 21.3 million tons of gasoline and diesel were used by four-wheeler passenger and commercial vehicles. If the distances driven by these cars be it is estimated that over 50 billion units of energy would have been required to charge the EVs over the corresponding EV-km. This is equivalent to 3.2% of the power produced during the same fiscal year. The Central Electricity Authority estimates that India has 31 GW of installed solar power producing capacity. This indicates that there is enough electricity for EVs. But all we need is a strategy to establish charging stations, which would require power distribution firms, for instance, to modify their transmission systems to accommodate the demand from EVs. Experts highlight this segment's business potential. There are several alternatives available for power and battery players. Even EV charging stations open up opportunities for small-scale commercial initiatives. This might boost the "Made in India" campaign and provide opportunities for Indian enterprises. India can reduce its dependence on imported gas and oil by expanding these markets. Another fantastic possibility which may be obtained is via storing extra solar power in EV batteries which can be sold back to the grid. In conclusion, the introduction of electric vehicles (EVs) represents a significant shift towards environmentally friendly transportation, offering a number of benefits including lower greenhouse gas emissions and a decreased need on fossil fuels.

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A Survey on the Evolution of Autonomous Agents: Trends, Challenges, and Future Directions

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Abstract: Over the past few decades, autonomous agents have undergone tremendous evolution, moving from rule-based systems to highly adaptive, learning-driven architectures. These autonomously perceivable, reasoning, and acting agents have found use in robotics, healthcare, finance, and other fields. This survey provides a comprehensive overview of the evolution of autonomous agents, highlighting key technological advancements, emerging trends, and persistent challenges. We explore the role of deep reinforcement learning, multi-agent systems, neuro symbolic AI, and edge computing in enhancing agent autonomy. Additionally, we discuss critical challenges such as generalization, safety, scalability, and ethical considerations. Finally, we outline future research directions, emphasizing the need for robust generalization techniques, improved human-agent collaboration, and the integration of quantum computing and self-supervised learning. This study acts as an important tool for researchers and practitioners aiming to comprehend the present scenario and prospective of autonomous agents.

Keywords: Autonomous Agents, Reinforcement Learning, Multi-Agent Systems, Explainable AI, Edge AI, AI Ethics

I. INTRODUCTION

Autonomous agents have become a fundamental component of artificial intelligence (AI), enabling machines to perceive their environment, make decisions, and act independently to achieve specific goals. These agents operate across various domains, including robotics, self-driving vehicles, financial trading, smart grids, and healthcare systems. The evolution of autonomous agents has been driven by advancements in machine learning, reinforcement learning, multi-agent coordination, and computational power, allowing for increasingly sophisticated decision-making capabilities.

The majority of early autonomous agents were rule-based, responding to certain inputs using pre-established heuristics. However, contemporary agents now have the capacity to learn from their surroundings, adjust to changing conditions, and gradually enhance their performance because to the development of deep learning and reinforcement learning. These agents' skills have been further improved by the combination of deep reinforcement learning (DRL), multi-agent systems (MAS), and neuro symbolic AI, which enables them to function in intricate, high-dimensional environments with little assistance from humans.

Despite these advancements, significant challenges remain. Autonomous agents often struggle with generalization across unseen tasks, ensuring robustness in real-world conditions, and maintaining safety in high-stakes environments. Additionally, ethical concerns such as transparency, accountability, and fairness continue to be critical issues in deploying these agents in human-centric applications.[9]

This survey aims to provide a comprehensive overview of the evolution of autonomous agents, covering key trends, persistent challenges, and promising future directions. We examine how the field has progressed from rule-based systems to intelligent, self-learning agents and analyze the current state of research in areas such as reinforcement learning, explainable AI, and human-agent collaboration. Finally, we discuss emerging technologies and research opportunities that could shape the next generation of autonomous agents, including quantum computing, neuromorphic hardware, and self-supervised learning.[10]

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1.1 Importance of Autonomous Agents

Autonomous agents play a critical role in modern AI systems by enabling intelligent decision-making, automation, and adaptability in dynamic environments. Unlike traditional software programs, these agents possess the ability to perceive their surroundings, learn from interactions, and take actions without human intervention. Their growing importance stems from several key factors:[11]

- **Scalability and Efficiency:** Autonomous agents can handle complex decision-making tasks at scale, optimizing resource allocation and improving operational efficiency across various industries.
- **Adaptability and Learning:** Through reinforcement learning and advanced AI techniques, these agents continuously adapt to new challenges and improve over time.
- **Reduction in Human Effort:** By automating repetitive and high-risk tasks, autonomous agents minimize the need for human intervention, reducing errors and increasing productivity.
- **Enhancement of Decision-Making:** These agents assist in data-driven decision-making, providing real-time insights and intelligent responses in critical applications.

1.2 Applications in AI and Real-World Domains

Autonomous agents are transforming numerous domains, offering innovative solutions across industries. Below are some of the most significant applications:

1.2.1 Robotics and Autonomous Vehicles

- **Self-Driving Cars:** Autonomous driving systems, such as those developed by Tesla and Waymo, utilize AI agents to navigate, detect obstacles, and make real-time driving decisions.
- **Industrial and Service Robots:** AI-powered robots in manufacturing, warehouses, and customer service improve productivity by automating tasks such as assembly, logistics, and customer interactions.

1.2.2 Healthcare and Medical AI

- **AI-Powered Diagnosis and Treatment Planning:** Autonomous agents assist doctors in diagnosing diseases (e.g., AI models for radiology and pathology) and recommending personalized treatments.
- **Robotic Surgery:** Autonomous surgical robots enhance precision and reduce risks in medical procedures.
- **Healthcare Monitoring:** AI-driven agents in wearable devices monitor vital signs and detect early warning signs of health conditions.

1.2.3 Finance and Trading

- **Algorithmic Trading:** AI agents analyze market trends and execute trades autonomously, optimizing financial portfolios and risk management.
- **Fraud Detection:** Machine learning-powered agents detect anomalies and fraudulent transactions in banking and e-commerce.

1.2.4 Smart Cities and IoT

- **Traffic Management Systems:** AI-powered agents optimize traffic flow, reducing congestion and improving urban mobility.
- **Smart Grid Energy Management:** Autonomous agents balance energy distribution, predict demand, and optimize resource allocation for sustainable energy solutions.

1.2.5 Gaming and Entertainment

- **AI Opponents and NPCs:** Game AI agents enhance realism in video games by controlling non-player characters (NPCs) with advanced behaviors.
- **Personalized Content Recommendation:** AI-driven agents curate tailored content for users in streaming services like Netflix and Spotify.

1.2.6 Cybersecurity and Defense

- **Threat Detection and Response:** Autonomous agents detect and mitigate cyber threats by analyzing network traffic and identifying vulnerabilities.
- **Autonomous Drones and Surveillance:** AI-powered drones assist in surveillance, reconnaissance, and disaster response operations.

1.3. Evolution from Rule-Based Systems to Intelligent Agents

The development of autonomous agents has undergone a significant transformation over the past few decades, evolving from simple rule-based systems to highly sophisticated, intelligent agents capable of learning and adapting to dynamic environments. This progression has been driven by advancements in artificial intelligence (AI), machine learning, and computational power.

1.3.1 Early Rule-Based Systems

The initial generation of autonomous agents relied on **rule-based systems**, where decision-making was governed by explicitly defined rules and heuristics. These systems operated on **if-then-else logic**, following predefined instructions for every possible scenario.

- **Expert Systems (1970s–1980s):** These systems encoded domain-specific knowledge using **decision trees and symbolic reasoning** to make automated decisions. Examples include MYCIN (for medical diagnosis) and DENDRAL (for chemical analysis).
- **Limitations:** Rule-based systems struggled with handling **uncertainty, scalability, and adaptability** to unseen situations. They required manual rule updates, making them rigid and impractical for complex real-world applications.

1.3.2 Emergence of Reactive and Deliberative Agents

As AI research progressed, autonomous agents transitioned into **reactive and deliberative architectures**, enhancing their flexibility and problem-solving capabilities.

- **Reactive Agents (1980s–1990s):** Inspired by **behavior-based AI**, reactive agents followed **simple stimulus-response mechanisms**. They were efficient for real-time decision-making but lacked long-term planning. Example: Rodney Brooks' **Subsumption Architecture**, used in early mobile robots.
- **Deliberative Agents (1990s):** These agents incorporated **symbolic reasoning and planning algorithms (e.g., STRIPS, A* search)**, enabling goal-oriented behavior and strategic decision-making. They combined **world models and logical inference** but suffered from computational inefficiencies in large state spaces.

1.3.3 Learning-Based Autonomous Agents

With the rise of **machine learning and reinforcement learning (RL)** in the 2000s, autonomous agents evolved beyond hand-crafted rules, enabling them to learn optimal behaviors through data-driven approaches.

- **Supervised and Unsupervised Learning (2000s):** Agents started leveraging statistical learning models (e.g., neural networks, support vector machines) to **classify, predict, and adapt to patterns** in their environments.
- **Reinforcement Learning (RL) (2010s):** RL-based agents, particularly those using **Deep Reinforcement Learning (DRL)**, gained the ability to optimize decision-making by interacting with dynamic environments. Breakthroughs include

- **Deep Q-Networks (DQN)**: Used in Atari games for self-learning agents.
- **AlphaGo and AlphaZero**: Mastered complex games like Go and Chess through self-play and reinforcement learning.
- **Autonomous Vehicles and Robotics**: RL-enabled self-driving cars and robotic systems capable of adapting to real-world uncertainties.

1.3.4 Multi-Agent Systems and Collaborative Intelligence

As applications grew more complex, **multi-agent systems (MAS)** became prominent, allowing multiple autonomous agents to **collaborate, compete, and coordinate** their actions.

- **Swarm Intelligence:** Inspired by nature (e.g., ant colonies, flocking birds), these decentralized agent systems optimize decision-making without a central controller.
- **Game Theory & Strategic Learning:** AI agents use **multi-agent reinforcement learning (MARL)** to negotiate, cooperate, and adapt in dynamic environments. Applications include smart traffic systems, autonomous drones, and competitive AI in strategic games.

1.3.5 The Rise of Neurosymbolic and Explainable AI (XAI)

Modern intelligent agents are now integrating **neuro symbolic AI**, combining **deep learning with symbolic reasoning** to improve explainability, reasoning, and common-sense understanding.

- **Hybrid AI Systems:** These systems blend **neural networks (for perception and pattern recognition)** with **symbolic AI (for logic-based reasoning and planning)**, improving interpretability.
- **Explainable AI (XAI):** Increasing transparency in autonomous decision-making to enhance trust, particularly in high-stakes applications like healthcare and finance.

1.3.6 Towards the Future: Generalized and Human-Centric Agents

Future autonomous agents are expected to achieve **higher levels of generalization, adaptability, and human collaboration** through:[12]

- **Self-Supervised Learning (SSL):** Enabling agents to learn from vast amounts of unlabeled data without human intervention.
- **Neuro-Inspired AI:** Developing AI architectures that mimic the brain's cognitive processes for more robust learning.
- **Quantum AI:** Leveraging quantum computing for exponentially faster decision-making in complex multi-agent environments.
- **Human-Agent Collaboration:** Advancing **interactive AI systems** where agents work alongside humans in decision-making, robotics, and creative tasks.

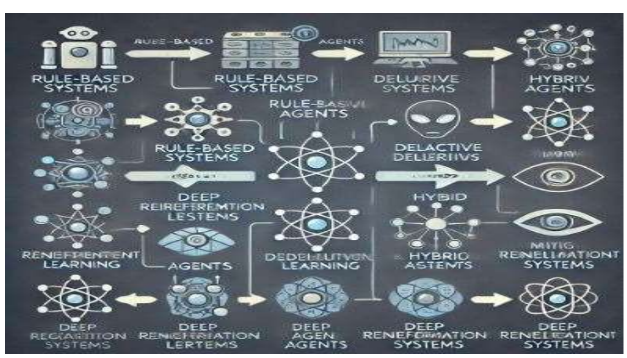

Fig.1 Evolution of Autonomous Agents

II. FOUNDATIONS OF AUTONOMOUS AGENTS

Autonomous agents are intelligent entities capable of perceiving their environment, making decisions, and executing actions to achieve specific goals. This section covers the theoretical background of agent-based modeling and decision-making frameworks, the core components of autonomous agents, and a comparison of different agent architectures.[1]

2.1 Theoretical Background: Agent-Based Modeling and Decision-Making Frameworks

2.1.1 Agent-Based Modeling (ABM)

Agent-Based Modeling (ABM) is a computational approach used to simulate complex systems by modeling individual agents and their interactions within an environment. ABM is widely used in **economics, social sciences, robotics, and artificial life simulations** to study emergent behaviors and decentralized decision-making.

- **Definition**: A system where multiple autonomous agents interact within a defined environment based on predefined rules or learning mechanisms.
- **Properties of ABM**:
  - **Autonomy** – Agents operate independently.
  - **Interactivity** – Agents communicate and influence each other.
  - **Adaptability** – Agents learn and evolve over time.
- **Applications**: Smart cities, traffic simulations, epidemic modeling, swarm robotics, and market simulations.

2.1.2 Decision-Making Frameworks in Autonomous Agents

Decision-making is a fundamental capability of autonomous agents. Various frameworks exist to model how agents perceive their environment, evaluate possible actions, and execute optimal decisions. Some key frameworks include:

- **Markov Decision Processes (MDP)**
  - A formal mathematical framework used for modeling decision-making in stochastic environments.
  - Defined as **(S, A, P, R, γ)**, where:
    - **S**: Set of states
    - **A**: Set of actions
    - **P**: Transition probability function
    - **R**: Reward function
    - **γ**: Discount factor for future rewards
  - Used in reinforcement learning for optimal policy learning.
- **Partially Observable Markov Decision Processes (POMDPs)**
  - Extends MDPs to environments where agents have **limited observability**.
  - Useful in robotics, self-driving cars, and complex AI planning problems.
- **Game Theory & Multi-Agent Decision Making**
  - Models competitive and cooperative behavior between multiple agents.
  - Used in economic modeling, autonomous trading, and multi-agent reinforcement learning.

2.2 Core Components of Autonomous Agents

Autonomous agents are composed of several key components that enable perception, reasoning, decision-making, and action.[2]

2.2.1 Perception

- Involves sensing and interpreting environmental data.
- Uses sensors, computer vision, and natural language processing (NLP) to perceive the world.
- Examples: Cameras in self-driving cars, LiDAR for obstacle detection, speech recognition in voice assistants.

2.2.2 Planning

- Determines the sequence of actions required to achieve a goal.
- Common planning techniques:

    - **Classical Planning**: A* search, Dijkstra's algorithm.
    - **Probabilistic Planning**: Monte Carlo Tree Search (MCTS), Markov Decision Processes (MDPs).
    - **Task and Motion Planning (TAMP)**: Used in robotics for pathfinding and manipulation.

2.2.3 Learning

- Learning mechanisms allow agents to improve performance over time.
- Categories of learning:

    - **Supervised Learning**: Learning from labeled datasets.
    - **Unsupervised Learning**: Detecting patterns without labels.
    - **Reinforcement Learning (RL)**: Learning via reward-based exploration.

- Example: **AlphaZero**, which learned chess, Go, and shogi through reinforcement learning.

2.2.4 Action

- Execution of planned actions based on decision-making models.
- Involves motion control in robots, recommendation generation in AI systems, and response mechanisms in virtual assistants.

2.3 Comparison of Reactive, Deliberative, and Hybrid Agents

2.3.1 Reactive Agents

- **Definition**: Agents that respond to stimuli without internal models or planning.
- **Mechanism**: Rule-based, direct mapping from perception to action.

- **Advantages**:

    - Fast and computationally efficient.
    - Works well in real-time, dynamic environments.

- **Disadvantages**:

    - Lacks memory and planning.
    - Cannot handle complex decision-making.

- **Example**: Subsumption architecture in mobile robots (Rodney Brooks, 1986).

2.3.2 Deliberative (Cognitive) Agents

- **Definition**: Agents that use world models, reasoning, and planning to make decisions.
- **Mechanism**: Uses symbolic reasoning, search algorithms, and planning frameworks.
- **Advantages**:
    - Can handle long-term planning and decision-making.
    - Better suited for high-level reasoning tasks.

- **Disadvantages**:
    - Computationally expensive.
    - Less effective in highly dynamic environments.
- **Example**: AI chess engines, planning systems in robotics.

2.3.3 Hybrid Agents

- **Definition**: Combines reactive and deliberative approaches for efficiency and robustness.
- **Mechanism**: Uses layered architectures where reactive components handle low-level control, while deliberative components handle high-level reasoning.
- **Advantages**:
    - Balances speed and intelligence.
    - More scalable for real-world applications.
- **Disadvantages**:
    - Complexity in designing hybrid architectures.
- **Example**:
    - **Shakey the Robot (1970s)** – Combined perception, planning, and execution.
    - **Modern self-driving cars** – Use deep learning for perception (reactive) and rule-based decision-making for navigation (deliberative).

III. KEY TRENDS IN AUTONOMOUS AGENTS

The field of autonomous agents is rapidly evolving, driven by advancements in artificial intelligence (AI), machine learning, and computational power. This section highlights the key trends shaping the development of autonomous agents, including deep reinforcement learning, multi-agent collaboration, explainability, human-agent interaction, and emerging hardware innovations.[3]

3.1 Deep Reinforcement Learning and Self-Learning Agents

Recent progress in **Deep Reinforcement Learning (DRL)** has significantly enhanced the capabilities of autonomous agents, enabling them to learn complex behaviors from trial and error.[4]

- **Advancements in DRL:**
    - **Deep Q-Networks (DQN)**: Used in game-playing AI like Atari agents.
    - **Policy Gradient Methods (PPO, A3C, SAC)**: Applied in robotics and continuous control tasks.
    - **AlphaZero & MuZero**: Achieved superhuman performance in chess, Go, and video games.
- **Self-Supervised and Unsupervised Learning:**
    - Reduces reliance on labeled data.
    - Enables agents to learn representations from large-scale, unstructured environments.

Example: OpenAI's GPT-4 and DeepMind's AlphaZero showcase self-learning paradigms that extend beyond predefined rule-based systems.

3.2 Multi-Agent Systems and Cooperative AI

With increasing complexity in real-world applications, autonomous agents are shifting from **individual intelligence** to **collaborative multi-agent systems (MAS)**.

- **Multi-Agent Reinforcement Learning (MARL):**
    - Enables agents to **collaborate, negotiate, and compete** in shared environments.
    - Used in autonomous traffic control, robotic swarms, and distributed AI systems.

- **Swarm Intelligence:**
  - Inspired by biological systems (e.g., ants, bees, flocking birds).
  - Applied in drone coordination, military defense, and smart grid management.
- **Game Theory for Strategic Interactions:**
  - Models cooperative and competitive decision-making between autonomous entities.

Example: StarCraft II AI agents developed by DeepMind demonstrated advanced **multi-agent coordination** in strategic gameplay.

3.3 Explainability and Trustworthy AI (XAI)

As autonomous agents become more sophisticated, ensuring their **transparency, interpretability, and fairness** is crucial for adoption in high-stakes applications.

- **Explainable AI (XAI) Methods:**
  - **Post-hoc explainability:** Feature attribution (e.g., SHAP, LIME).
  - **Intrinsic explainability:** Rule-based and symbolic reasoning models.
- **Challenges in Black-Box AI Systems:**
  - Lack of interpretability in deep learning models raises concerns in **healthcare, finance, and autonomous driving**.
- **Regulatory Compliance and Ethics:**
  - AI governance frameworks like **EU AI Act** and **AI Bill of Rights** emphasize fairness, accountability, and transparency.

Example: IBM's AI Explainability 360 toolkit provides insights into **model decision-making** for regulatory and ethical compliance.

3.4 Human-Agent Collaboration and Interactive AI

As AI becomes more embedded in society, designing **human-compatible agents** that can interact, assist, and collaborate with humans is a major trend.

- **Conversational AI & Virtual Assistants:**
  - Chatbots like **ChatGPT, Google Bard, and Amazon Alexa** enhance human-AI interaction.
- **AI-Augmented Decision-Making:**
  - AI assists in **finance, law, medicine**, acting as **decision-support systems** rather than full automation.
- **Human-Agent Teams (HATs):**
  - AI assists in **robotics, healthcare, and military operations**, optimizing **human-in-the-loop** systems.

Example: NASA's **Robonaut** works alongside astronauts in space missions, improving safety and efficiency.

3.5 Autonomous Vehicles and Robotics

The integration of AI in **self-driving cars, drones, and industrial robots** is revolutionizing automation across industries.

- **Autonomous Vehicles:**
  - Companies like Tesla, Waymo, and Cruise deploy AI-powered **self-driving systems** using **sensor fusion, computer vision, and deep learning**.
- **AI in Robotics:**
  - Advances in **robotic perception, dexterous manipulation, and reinforcement learning** enable robots to handle **unstructured environments**.

- **Soft Robotics & Bio-Inspired Designs:**
  - Mimicking **biological flexibility and adaptability** to improve robotic movements.

Example: Boston Dynamics' Atlas robot demonstrates **dynamic locomotion and real-time adaptability** in changing environments.

3.6 Edge AI and Energy-Efficient Autonomous Agents

Deploying AI on **edge devices** instead of centralized cloud servers is a growing trend, making autonomous agents more **responsive, scalable, and energy-efficient**.

- **Edge AI & On-Device Inference:**
  - Reduces latency in real-time decision-making (e.g., autonomous drones, smart cameras).
- **Neuromorphic Computing & AI Hardware:**
  - Brain-inspired chips (e.g., Intel Loihi, IBM TrueNorth) enhance **AI efficiency** with low-power processing.
- **Green AI & Sustainable Agents:**
  - Focuses on reducing **carbon footprints of AI models**, optimizing energy usage in data centers and autonomous systems.

Example: Apple's **Neural Engine** enables **on-device AI computation**, reducing reliance on cloud processing.

3.7 Ethical AI and Societal Impact

As autonomous agents gain decision-making authority, ensuring **ethical considerations** and minimizing **societal risks** is crucial.

- **Bias and Fairness in AI:**
  - Addressing biases in AI decision-making (e.g., biased facial recognition, unfair hiring algorithms).
- **AI for Social Good:**
  - AI applications in **climate change, disaster response, and education**.
- **Regulations and AI Safety:**
  - Frameworks for responsible AI development to **prevent unintended consequences**.

Example: The **Partnership on AI** (PAI) is a multi-stakeholder initiative promoting **responsible AI development**.

IV. CHALLENGES IN AUTONOMOUS AGENTS

Generalization and Transfer Learning: Autonomous agents struggle to adapt to new, unseen environments. Transfer learning can help agents apply knowledge from one domain to another, but generalizing across varying scenarios remains a significant challenge.[5]

Safety and Robustness: Autonomous agents must be able to handle adversarial attacks and uncertainty. Ensuring that they perform reliably in unpredictable or hostile environments is crucial, especially in critical applications like self-driving cars and robotics.[6]

Scalability in Multi-Agent Systems: As the number of agents increases, coordination and communication become more complex. Agents need efficient methods to collaborate, share information, and avoid bottlenecks in decision-making.[7]

Ethical and Societal Considerations: Issues like bias in decision-making, lack of transparency in AI systems, and accountability for decisions made by autonomous agents are pressing concerns. Ensuring fairness, interpretability, and responsibility in agent behavior is essential for societal trust and adoption.[8]

V. FUTURE DIRECTIONS IN AUTONOMOUS AGENTS

The future of autonomous agents is poised to bring transformative advancements across various domains. Key directions include:

Fig.2 Future Direction of Autonomous Systems

Advancements in Generalization and Transfer Learning: Improving agents' ability to adapt quickly to new, unseen environments and tasks through more efficient transfer learning and meta-learning approaches.[13]

Enhanced Safety and Robustness: Developing more resilient systems that can operate in uncertain, adversarial environments, ensuring safety and reliability across high-risk applications like autonomous vehicles and healthcare.[14]

Scalable Multi-Agent Systems: Building more scalable solutions for multi-agent coordination, focusing on decentralized decision-making, efficient communication protocols, and resolving coordination bottlenecks in complex environments.[15]

Ethical and Responsible AI: Fostering the development of **explainable AI** and fairness-aware algorithms to address societal concerns, ensuring that autonomous agents make ethical, transparent decisions with clear accountability.[16]

Human-Agent Collaboration: Creating more intuitive and seamless collaboration between humans and autonomous agents, enhancing AI's role as a **support system** rather than fully autonomous decision-makers.

Edge AI and Energy Efficiency: Shifting towards **edge computing** for real-time decision-making, while improving the **energy efficiency** of autonomous systems, particularly in mobile robotics, drones, and IoT devices.

These future directions aim to refine autonomous agents' adaptability, safety, scalability, and ethical alignment, unlocking their potential across industries like healthcare, transportation, robotics, and entertainment.

VI. CONCLUSION

The evolution of autonomous agents represents a monumental shift in how intelligent systems are designed, developed, and deployed across various industries. From the early rule-based systems to the rise of sophisticated AI-driven agents leveraging deep learning, reinforcement learning, and multi-agent collaboration, autonomous agents are becoming increasingly capable of handling complex tasks in dynamic, real-world environments.

Despite the significant progress, the field still faces several challenges, including generalization to unseen environments, ensuring safety and robustness in adversarial scenarios, scalability in multi-agent systems, and addressing ethical concerns like bias, transparency, and accountability. Overcoming these challenges will be key to realizing the full potential of autonomous agents.

Looking ahead, the future of autonomous agents holds great promise, with advancements in generalization and transfer learning, enhanced safety mechanisms, and improved coordination in multi-agent systems. Ethical AI frameworks, human-agent collaboration, and energy-efficient solutions will also shape the next wave of autonomous agents, ensuring their integration into society in a responsible, transparent, and beneficial way.

In conclusion, while there are still hurdles to overcome, the ongoing research and development in autonomous agent technologies offer exciting opportunities for revolutionizing industries and improving quality of life through intelligent, autonomous systems. The future of autonomous agents is bright, with continuous innovation driving their evolution to create more adaptive, safe, and ethical systems.

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A Review on Explainable AI for Deepfake Detection Leveraging Hybrid Deep Learning Techniques

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Abstract: The advent of deepfake technology, leveraging advancements in generative artificial intelligence, has catalyzed a substantial threat to the integrity and trustworthiness of digital media. Deepfakes, which include hyper-realistic synthetic images, videos, and audio generated using techniques such as Generative Adversarial Networks (GANs), have been widely exploited to create fake content that is increasingly indistinguishable from reality. This work investigates the intersection of Explainable Artificial Intelligence (XAI) with deepfake detection, emphasizing the importance of transparency and interpretability in this field. We provide a detailed analysis of existing deepfake detection strategies, including Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and hybrid and multimodal approaches. The paper further emphasizes the importance of integrating XAI techniques to enhance model interpretability, reliability, and robustness, thus enabling more transparent and ethical AI systems. In addition, we assess various evaluation metrics and benchmark datasets utilized in deepfake detection research and discuss the limitations of current models. Finally, the paper outlines future research directions, advocating for continuous innovation and interdisciplinary collaboration to mitigate the pervasive threat posed by deepfake technology.

Keywords*:* Deepfake, Generative Adversarial Networks (GAN), Hybrid Models, Deep Learning, Explainable AI (XAI)

I. INTRODUCTION

The rapid proliferation of deepfake technology represents one of the most formidable challenges in the digital information landscape. Deepfake material, developed with deep learning models like GANs, may effectively duplicate an individual's look and speech, typically with malevolent intent. These manipulations pose serious risks, from spreading misinformation and political propaganda to undermining privacy and national security. The need for effective detection mechanisms has never been more critical, especially as the technology to create deepfakes becomes more accessible.

Deepfake content, which is produced with the use of deep learning models like GANs, may mimic people's speech and look quite well, frequently with malevolent intent. However, most detection models are complex, acting as "black boxes" whose decision-making processes are not easily interpretable. This opaqueness raises ethical and trust-related concerns, as the models' decisions cannot be easily justified or scrutinized, particularly in sensitive applications involving legal, political, or media contexts. Explainable AI (XAI) has been offered as a remedy for these issues. XAI seeks to make AI models more visible and intelligible, promoting informed trust and allowing stakeholders to comprehend and confirm the system's judgments.

This paper highlights the crucial role of XAI while offering a thorough analysis of deepfake detection techniques. We examine various techniques, including CNNs for spatial analysis, RNNs for temporal feature extraction, hybrid models that combine both, and advanced multimodal frameworks that integrate audio-visual cues. Furthermore, we explore how XAI methods can improve model interpretability and discuss the metrics and datasets used to benchmark these detection systems. Our analysis concludes with a discussion of the current limitations and recommendations for future research in this ever-changing field.

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II. LITERATURE REVIEW

The rapid advancement of deepfake technology has led to the development of numerous detection methods, each employing different approaches and architectures. Mas Montserrat et al. (2020) introduced a method combining convolutional and recurrent neural networks for efficient face manipulation detection, highlighting the importance of temporal analysis in deep-fake videos. Pashine et al. (2021) provided a comprehensive survey of facial manipulation detection techniques, comparing various CNN models like VGG-19, ResNet-50, and Xception, and underscoring the trade-offs between model complexity and accuracy. The efficacy of hybrid models, such as CNN-LSTM architectures, was further explored by Shaikh et al. (2023), who demonstrated how combining spatial and temporal feature extraction improves detection robustness. Additionally, Ismail et al. (2021) and Raza and Malik (2023) proposed innovative approaches incorporating multimodal frameworks, such as the YOLO-Face CNN-XGBoost model and Multimodal trace architecture, which jointly analyze audio and visual cues to enhance detection performance. To address challenges related to model interpretability and explainability, Groh et al. (2021) examined the role of Explainable AI (XAI), emphasizing the use of feature attribution and visualization techniques to make deepfake detection models more transparent and trustworthy. Collectively, these studies underscore the ongoing efforts to develop efficient, accurate, and interpretable deepfake detection systems, while also highlighting the necessity of future research that focuses on model generalizability and robustness against adversarial attacks.

III. DEEPFAKE DETECTION TECHNIQUES

Deepfake detection techniques have evolved significantly over time, primarily due to advances in deep learning and computer vision. The following subsections delve into the key methodologies used in this domain.

A. Convolutional Neural Networks (CNNs)

Convolutional Neural Networks (CNNs) are a cornerstone of deepfake detection, particularly adept at extracting spatial features from images and video frames. CNN-based models like VGG-19, ResNet-50, and Xception have been extensively utilized for their ability to learn intricate patterns and detect artifacts indicative of deepfake manipulations [5]. The Xception network, for instance, employs depth wise separable convolutions, making it both efficient and powerful in identifying subtle inconsistencies.

The performance of CNN models is often benchmarked on datasets like FaceForensics++ and Celeb-DF, where they achieve high detection accuracies [6]. However, these models face challenges when dealing with unseen deepfake variants, highlighting a lack of generalizability. Moreover, CNNs are susceptible to adversarial attacks and often require extensive computational resources for training and deployment. Despite these limitations, CNNs remain a fundamental component of deepfake detection systems, and ongoing research focuses on enhancing their robustness and efficiency.

B. Recurrent Neural Networks (RNNs) and Temporal Analysis

Temporal analysis is crucial in deepfake detection, especially for video content where temporal inconsistencies can be a tell-tale sign of manipulation. Recurrent Neural Networks (RNNs), specifically Long Short-Term Memory (LSTM) networks, are used to capture and analyze temporal dependencies between video frames [9]. For example, the YOLO-Face convolution recurrent approach combines a CNN for spatial feature extraction and a Bi-LSTM for temporal analysis, resulting in commendable performance on large-scale datasets [6]. The strength of RNN-based models lies in their ability to detect subtle temporal anomalies, such as unnatural head movements or frame-to-frame inconsistencies. These models are often trained on datasets like the DeepFake Detection Challenge (DFDC) and evaluated based on metrics like recall, precision, and the F1-score [4]. Nevertheless, RNNs are computationally intensive and may suffer from vanishing gradient problems, prompting researchers to explore more efficient architectures or hybrid approaches that mitigate these issues.

C. Hybrid Models

Hybrid models that combine CNNs and RNNs have gained traction in the deepfake detection landscape. These models make use of the advantages of both architectures: RNNs for temporal feature modeling and CNNs for spatial feature extraction. A prominent example is the CNN-LSTM architecture, which has demonstrated superior performance in detecting complex deepfake manipulations by capturing both spatial and temporal features [9].

Despite their effectiveness, hybrid models are not without limitations. They require substantial computational power and may exhibit reduced performance when faced with adversarially crafted deepfake content [8]. Moreover, their interpretability remains a concern, as the combination of multiple architectures adds to the complexity of the model.

Integrating XAI techniques into hybrid models could enhance their transparency and facilitate a better understanding of the decision-making process.

D. Multimodal Approaches

The use of multimodal data, such as audio and visual cues, has emerged as a promising strategy for deepfake detection. The Multimodal trace framework, for example, uses Intramodality and InterModality Mixer Layers to process audio and visual features together, achieving state-of-the-art accuracy on the FakeAVCeleb dataset [16]. These models can detect inconsistencies that are not visible when each modality is considered separately by analyzing the synchronization of the audio and visual modalities.

Multimodal approaches have demonstrated robustness in cross-dataset evaluations, making them suitable for real-world applications. However, they also present challenges, including increased model complexity and the need for large, diverse datasets that encompass various types of deepfake manipulations. Future research in this area is expected to explore alternative integration techniques, such as attention mechanisms and graph-based models, to improve both performance and interpretability [17].

TABLE: I
COMPARATIVE ANALYSIS OF EXISTING DEEPFAKE DETECTION TECHNIQUES

Technique	Model Type	Accuracy (%)	Computational Efficiency	Interpretability	Robustness
CNN-Based	Deep Learning	90-95	Moderate	Low	Moderate
RNN-Based	Deep Learning	85-92	High	Low	Moderate
Hybrid CNN-RNN	Hybrid Model	92-97	Moderate	Moderate	High
Transformer-Based	Deep Learning	93-98	Low	High	High
Handcrafted Features	Traditional ML	80-88	High	High	Low
GAN-Based Detection	Deep Learning	88-94	Moderate	Low	Moderate

IV. EXPLAINABLE AI IN DEEPFAKE DETECTION

The increasing complexity of deepfake detection models necessitates a focus on Explainable Artificial Intelligence (XAI) to make these systems transparent and understandable. As detection algorithms become more sophisticated, it becomes crucial for stakeholders—including researchers, policymakers, and the public—to comprehend how these models arrive at their decisions. This section delves into the role of XAI in deepfake detection, emphasizing its methods and the benefits of incorporating interpretability into AI models.

A. Feature Attribution and Visualization

Feature attribution techniques are fundamental in XAI, helping to highlight which features most influence a model's output. In the context of deepfake detection, feature attribution can identify specific facial regions or temporal segments of a video that contribute significantly to the decision of the model [12]. Methods like integrated gradients, Grad-CAM (Gradient-weighted Class Activation Mapping), and saliency maps are commonly used to visualize these attributions.

• Grad-CAM is particularly effective for CNN-based models, as it generates heatmaps that show which areas of an image are most important for a given classification [13]. For example, a Grad-CAM heatmap may reveal that a deepfake detector focuses on unnatural artifacts around the eyes or mouth, areas that are often difficult for generative models to replicate perfectly.

• Saliency maps can similarly be used to visualize which pixels or regions in an image influence the model's predictions. These maps provide insights into how the model perceives discrepancies in facial features, such as asymmetrical lighting or unnatural skin textures, which may be indicative of deepfake content [14].

Feature attribution not only aids researchers in understanding model behavior but also helps in debugging and refining detection algorithms. By identifying which features are most informative, developers can improve model robustness and efficiency [15]. Furthermore, these visualizations can be used to educate non-expert audiences about the strengths and limitations of deepfake detection technologies, fostering a more informed and skeptical public.

B. Model Transparency and Interpretability

Beyond feature attribution, model transparency encompasses the broader goal of making AI systems comprehensible at a structural and operational level. In deepfake detection, interpretability is crucial for several reasons:

Trust and Accountability: In applications where deepfake detection models are used for forensic purposes or media verification, understanding the model's reasoning is essential [16]. For instance, journalists or legal experts need to know why a model flagged a video as a deepfake, especially if the content has legal or societal implications

Bias Detection: XAI can help reveal biases in detection models. If a model consistently performs better or worse on certain demographic groups, interpretability tools can uncover these discrepancies, prompting the development of fairer algorithms [17]. For example, a model might exhibit bias against individuals with darker skin tones if it was trained on a dataset lacking sufficient diversity.

Techniques for enhancing model transparency include rule-based explanations, decision trees, and surrogate models that approximate the behavior of more complex neural networks [18]. LIME (Local Interpretable Model-agnostic Explanations) is one such tool that can explain individual predictions by approximating the deepfake detection model with an interpretable one [19].

Another emerging approach is the use of attention mechanisms in neural networks. Attention layers highlight which parts of an input the model is focusing on, making the decision-making process more interpretable [20]. For example, an attention-based model may allocate more focus to areas where facial artifacts are most pronounced, providing a clear rationale for its predictions.

V. EVALUATION METRICS AND DATASETS

The efficacy of deepfake detection models is often assessed using a combination of standard evaluation metrics and benchmark datasets. These metrics and datasets play a crucial role in establishing the reliability and robustness of different detection methods.

A. Evaluation Metrics

In deepfake detection, evaluation metrics such as accuracy, precision, recall, F1-score, and the Area Under the Receiver Operating Characteristic Curve (AUROC) are frequently employed. Different viewpoints on model performance are offered by each of these metrics:

The percentage of accurate predictions among all predictions is known as accuracy. Accuracy is helpful, but if the dataset is unbalanced, it can be deceptive because it ignores false positives and false negatives.

Precision and Recall offer a more nuanced view. Precision indicates how many of the detected deepfakes are truly deepfakes, while recall measures how many actual deepfakes were correctly identified. These metrics are crucial in scenarios where false positives or false negatives have severe consequences.

A balanced metric that is especially helpful when working with imbalanced datasets is the F1-score, which is the harmonic mean of precision and recall.

AUROC assesses how well the model can differentiate between classes at various threshold values. A model that performs well in distinguishing between authentic and fraudulent content under various circumstances is indicated by a high AUROC value.

In addition to these metrics, latency and computational efficiency are important considerations for real-time applications, such as social media platforms that need to screen uploaded content. The robustness of a model, often tested through adversarial attacks, is another critical metric, as it measures the model's resilience to intentional manipulations designed to evade detection.

B. Benchmark Datasets

The development and evaluation of deepfake detection models rely heavily on publicly available datasets. These datasets vary in size, complexity, and the types of manipulations they include. Some of the most popular datasets are:

• **FaceForensics++:** This dataset includes over 1.8 million manipulated images and videos created using four different deepfake generation methods. It provides a benchmark for testing the effectiveness of detection models, particularly in the presence of compression artifacts and low-quality videos.

• **Celeb-DF (V2):** Known for its high-quality deepfake videos, Celeb-DF (V2) presents a significant challenge for detection models. The dataset addresses limitations found in earlier datasets, such as unnatural head poses and low visual quality, by offering more realistic manipulations.

• **DeepFake Detection Challenge (DFDC):** Created by Facebook in collaboration with other institutions, the DFDC dataset contains over 100,000 videos with a diverse set of actors and deepfake techniques. It serves as a comprehensive resource for evaluating model performance on a large and varied dataset.

• **WildDeepfake:** This real-world dataset includes deepfake videos collected from the internet, making it a more challenging testbed for detection models. Unlike controlled datasets, WildDeepfake features diverse scenes and lighting conditions, reflecting the complexities of real-world scenarios.

The choice of dataset significantly influences a model's performance and generalizability. While some models excel on specific datasets, they may struggle with others, highlighting the need for cross-dataset evaluations. Moreover, dataset diversity is crucial for training robust models that perform well across different demographics and environmental conditions.

VI. LIMITATIONS AND FUTURE DIRECTIONS

Despite significant advancements, deepfake detection models face several limitations. These include issues related to generalizability, computational efficiency, and the ever-evolving nature of deepfake generation techniques. Most detection methods are optimized for specific types of manipulations and may falter when confronted with novel or highly sophisticated deepfakes. Additionally, the reliance on large and diverse datasets poses challenges, as obtaining and annotating such data is resource-intensive.

Future research should focus on developing models that can generalize across different domains and withstand adversarial attacks. Hybrid and multimodal approaches that combine visual, audio, and contextual data hold promise for improving detection accuracy and robustness. Moreover, the integration of XAI techniques will be critical for making these models more transparent and trustworthy. Interdisciplinary collaboration among AI researchers, ethicists, and policymakers will also be essential in addressing the ethical and societal implications of deepfake technology.

VII. CONCLUSION

In conclusion, the integration of Explainable AI in deepfake detection offers a path toward more transparent, interpretable, and reliable AI systems. As deepfake technology continues to advance, the need for robust and explainable detection methods becomes increasingly urgent. By combining state-of-the-art detection techniques with XAI principles, researchers can build systems that are not only effective but also ethically sound and trustworthy. This paper provides a comprehensive overview of the current landscape in deepfake detection and highlights the critical role of XAI in shaping the future of this rapidly evolving field.

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Sustainable Water Management in Agriculture: Wastewater Treatment and IoT-Enabled Automated Irrigation

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Abstract: Water scarcity and ineffective water utilisation in agriculture provide considerable obstacles to global food security and environmental sustainability. This study investigates the amalgamation of wastewater treatment and IoT-enabled automated irrigation systems as pioneering approaches for sustainable water management in agriculture. Farmers can diminish reliance on freshwater by treating and reusing wastewater, while IoT-enabled irrigation systems enhance water utilisation via real-time monitoring, data analysis, and precise control. This study assesses the technical, economic, and environmental advantages of integrating various technologies, emphasizing their capacity to improve water efficiency, crop productivity, and resource conservation. Case studies and experimental findings illustrate the efficacy of IoT-enabled devices in minimising water waste and enhancing irrigation scheduling. The report also examines the obstacles to using these technologies, including as expenses, infrastructure, and farmer uptake. The results highlight the revolutionary potential of combining wastewater treatment with IoT-based irrigation to attain sustainable agricultural practices, enhance water conservation, and facilitate the shift towards a circular economy in agriculture. This study offers practical insights for policymakers, agricultural stakeholders, and technology developers to further scalable and sustainable water management strategies.

Keywords: Sustainable agriculture, wastewater treatment, IoT-enabled irrigation, water efficiency, precision farming, circular economy, resource conservation.

I. INTRODUCTIONS

Water is fundamental to agricultural output, a sector that utilizes around 70% of the world's freshwater resources [1]. The increasing global population, along with the intensifying effects of climate change, has exerted unparalleled strain on freshwater resources. The United Nations reports that over 2.3 billion individuals presently reside in water-stressed areas, a figure anticipated to escalate with the growing demand for agricultural commodities [2]. Inefficient water management methods, including excessive irrigation and dependence on non-renewable groundwater supplies, have intensified the issue, resulting in aquifer depletion, soil salinization, and diminished agricultural production [3]. These difficulties highlight the pressing necessity for creative and sustainable water management solutions in agriculture.

The agricultural sector faces a pivotal moment, since conventional methods are inadequate to satisfy the requirements of a swiftly evolving globe. Climate change has modified precipitation patterns, resulting in increased frequency and severity of droughts in certain areas and excessive rainfall in others [4]. These alterations have disturbed conventional agricultural practices, compelling farmers to adjust to new circumstances. The global population is anticipated to exceed 9.7 billion by 2050, hence escalating the demand for food and, subsequently, water [5]. The combined pressures of climate change and population increase have become water scarcity one of the most urgent concerns of the 21st century.

The effective utilization of water resources in agriculture has emerged as a key priority. Conventional irrigation techniques, such flood irrigation, exhibit considerable inefficiency, resulting in substantial water loss due to evaporation, runoff, and deep percolation [6]. These inefficiencies squander valuable water resources and exacerbate environmental degradation, including soil erosion and waterlogging. Furthermore, the excessive withdrawal of groundwater for irrigation has resulted in the depletion of aquifers, jeopardizing the long-term viability of agricultural systems [7].

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One of the most promising avenues for addressing water scarcity in agriculture is the integration of wastewater treatment and IoT-enabled automated irrigation systems. Wastewater, when properly treated, can serve as a reliable and sustainable alternative water source for irrigation, reducing the strain on freshwater resources and promoting a circular economy in agriculture [8]. Advances in wastewater treatment technologies have made it possible to safely reuse treated water for crop irrigation, even in water-scarce regions. However, the adoption of treated wastewater in agriculture requires careful consideration of water quality, crop suitability, and potential environmental impacts.

The repurposing of cleaned wastewater in agriculture provides numerous advantages. Initially, it offers a dependable water source that is less vulnerable to seasonal fluctuations and the effects of climate change. Secondly, it diminishes the demand for freshwater, facilitating its allocation to other essential purposes, such as potable water and ecosystem conservation. Third, cleansed wastewater frequently contains nutrients like nitrogen and phosphorus, which can diminish the necessity for synthetic fertilisers, hence reducing production costs and mitigating environmental damage [9]. The utilisation of treated wastewater in agriculture presents problems, including possible dangers to human health and the environment if inadequately handled. These dangers can be alleviated with rigorous water quality regulations, sophisticated treatment technology, and suitable irrigation practices.

The emergence of the Internet of Things (IoT) has transformed agricultural methods, especially in irrigation. IoT-enabled irrigation systems utilise real-time data from sensors, meteorological forecasts, and soil moisture assessments to optimise water consumption, assuring accurate and effective irrigation. These technologies can markedly diminish water waste, enhance agricultural yields, and cut operational expenses for farmers. Integrating IoT technologies with wastewater treatment enables the establishment of a closed-loop system that optimises water efficiency and reduces environmental consequences [10].

IoT-enabled irrigation systems provide numerous benefits compared to conventional approaches. Initially, they furnish real-time information regarding soil moisture levels, meteorological circumstances, and crop water needs, empowering farmers to make informed decisions about the timing and quantity of irrigation. This accuracy minimises water waste and guarantees that crops have the ideal quantity of water, enhancing yields and quality. Secondly, IoT solutions can be automated, diminishing the labour necessary for irrigation and enabling farmers to concentrate on alternative responsibilities. Third, these systems can be connected with additional smart farming technology, such as drones and satellite imagery, to deliver a holistic perspective of agricultural conditions and enhance resource utilisation [11].

Notwithstanding their potential, the extensive implementation of these technologies encounters numerous obstacles. Significant initial expenses, insufficient technical proficiency, and inadequate infrastructure in remote regions frequently obstruct the deployment of modern water management systems [11]. Moreover, farmers may exhibit reluctance to embrace new technologies owing to apprehensions of reliability, maintenance, and return on investment. Overcoming these obstacles necessitates a comprehensive strategy encompassing policy endorsement, financial incentives, and capacity-building activities.

This research aims to investigate the synergies between wastewater treatment and IoT-enabled irrigation systems to establish a sustainable water management framework for agriculture. This study seeks to deliver actionable insights for stakeholders throughout the agricultural value chain by analysing the technical, economic, and environmental aspects of these innovations.

The research assesses treated wastewater as a viable irrigation resource, emphasising its quality, safety, and effects on crop output and soil health. It evaluates the efficacy of IoT-enabled irrigation systems in optimising water utilisation, minimising waste, and enhancing crop yield. It also tackles issues and offers legislative ideas for sustainable water management techniques.

II. MATERIAL & METHODOLOGY

A. Sample Collection and it's characterization

The materials used in this study were carefully selected to ensure the successful implementation of wastewater treatment and IoT-enabled automated irrigation systems for sustainable water management in agriculture.

Municipal wastewater collected from a local wastewater treatment plant. The wastewater contained organic matter, nutrients (nitrogen and phosphorus), suspended solids, and trace amounts of heavy metals. The initial quality of the wastewater was analyzed for parameters such as biochemical oxygen demand (BOD), chemical oxygen demand

(COD), total dissolved solids (TDS), pH, Nitrate, Phosphate and Potassium.

B. IoT-Enabled Automated Irrigation systems

The PIC 16F877A is the microcontroller that was being utilised in this research. A microcontroller with 8 bits is used for this purpose. In addition to managing the relay that is connected to the motor, the microcontroller is responsible for receiving the readings from the soil moisture sensor, displaying the necessary messages on the LCD, and regulating the relay. The amount of water that is contained in the soil can be determined with the use of a soil moisture sensor. An LM358 that functions as a comparator and a pot that allows the sensitivity of the sensor to be altered are the components that make up this device. The prongs are required to be plugged into the ground.

C. Fabrication of water filtration systems

The unit filtration model was fabricated, for wastewater filtration. Wastewater treatment involves designing and constructing a multi-stage filtration system to remove contaminants and produce treated water suitable for irrigation or other non-potable uses. The materials used for designing the filtration unit was activated alumina, zeolite, activated alumina supported by gravels. The filter having base material of gravel of 5 cm thickness, and filter materials of Activated alumina, Zeolite and Activated carbon of each 5 cm thickness.

TABLE I:

INSTRUMENTS USED

Instrument	**Specification**	**Purpose**
Soil Moisture Sensor	LM358	Measures soil moisture levels
Microcontroller	PIC 16F	Receiving readings from sensor
LCD Display	16x2	Displays real-time moisture data
Filtration System	Activated alumina, zeolite, activated carbon	Treats wastewater

III. RESULT AND DISCUSSION

A. Physiochemical analysis

The physicochemical analysis of the collected wastewater revealed significant contamination, highlighting the need for proper treatment before agricultural reuse. The initial pH of the wastewater ranged from 6.2 to 7.1, indicating slightly acidic to neutral conditions. Electrical conductivity (EC) values were recorded between 1200 and 1800 µS/cm, suggesting moderate salinity levels, which could pose risks of soil salinization over long-term irrigation. The Total Dissolved Solids (TDS) ranged from 800 to 1500 mg/L, exceeding the recommended limit of 500 mg/L for irrigation, indicating the presence of dissolved inorganic salts and organic matter [12] High TDS levels, if not managed properly, can lead to soil salinity, affecting plant growth and water uptake.

The organic pollution indicators, Biological Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD), were significantly high, with BOD_5 values ranging between 150–350 mg/L and COD levels from 450–900 mg/L, exceeding standard limits [13]. These values indicated a substantial presence of biodegradable and non-biodegradable organic compounds, necessitating secondary and tertiary treatment to make the water suitable for agricultural use. The nutrient analysis showed that nitrate (NO_3^-) concentration ranged from 15 to 40 mg/L, exceeding the permissible limit of 10 mg/L [14], which can lead to groundwater contamination if improperly managed. Phosphate (PO_4^{3-}) levels varied between 2.5 and 8 mg/L, while potassium (K^+) concentrations were recorded between 20 and 50 mg/L, both of which can contribute to plant nutrition but require careful monitoring to prevent excessive accumulation in soil.

TABLE II:

PHYSIOCHEMICAL ANALYSIS OF WASTEWATER

Parameter	Untreated Water (Pre Filtration)	Treated Water (Post Filtration)	Standard Limits (FAO)
pH	6.2 - 7.1	7.0 - 7.5	6.5 - 8.5
EC (µS/cm)	1200 - 1800	750 - 1000	<1000
TDS (mg/L)	800 - 1500	450 - 750	<500
BOD5 (mg/L)	150 - 350	10 - 25	<30
COD (mg/L)	450 - 900	50 - 120	<150
Nitrate (mg/L)	15 - 40	5 - 10	<10
Phosphate (mg/L)	2.5 - 8	0.8 - 2.5	<2.5

B. Characteristics of filtered water

The filtration process significantly improved the physicochemical quality of the wastewater, making it more suitable for agricultural reuse. The filtered water was analyzed for key parameters, including pH, electrical conductivity (EC), total dissolved solids (TDS), biological oxygen demand (BOD5), chemical oxygen demand (COD), and microbial content, to assess its suitability for irrigation.

One of the most notable improvements was observed in pH stabilization, where the initial wastewater pH, which ranged from 6.2 to 7.1, was adjusted to 7.0–7.5 after filtration. This slight increase towards neutral pH is beneficial for plant growth, as extreme acidity or alkalinity can hinder nutrient uptake in crops [15]. Electrical conductivity (EC) showed a notable reduction from 1200–1800 µS/cm to 750–1000 µS/cm, which is within the permissible limits for irrigation water. The reduction in EC indicates the effective removal of excess dissolved ions, thereby lowering the risk of soil salinization and improving long-term agricultural sustainability [16].

The total dissolved solids (TDS) content decreased from 800–1500 mg/L to 450–750 mg/L, achieving a 40–50% reduction through filtration. This is crucial for irrigation as high TDS levels can lead to salt accumulation in the soil, affecting soil structure and crop productivity. Additionally, the filtration system effectively lowered biological oxygen demand (BOD_5) from 150–350 mg/L to 10–25 mg/L, achieving an 85–95% reduction, while chemical oxygen demand (COD) decreased from 450–900 mg/L to 50–120 mg/L, demonstrating a significant removal of organic pollutants.

These reductions align with previous studies that highlight the efficiency of sand filtration, activated carbon filtration, and membrane filtration in removing organic pollutants and improving water clarity. Another critical aspect of filtration was its ability to remove harmful nutrients and heavy metals. The nitrate (NO_3^-) concentration reduced from 15–40 mg/L to 5–10 mg/L, bringing it within the acceptable limits for irrigation, which is essential to prevent nitrogen leaching into groundwater. Phosphate (PO_4^3) levels decreased from 2.5–8 mg/L to 0.8–2.5 mg/L, ensuring controlled nutrient release for plant growth while mitigating the risk of eutrophication in nearby water bodies. Potassium (K^+) levels were slightly reduced but remained within beneficial limits for crops.

C. Working of circuit

The aim of the research is to create an autonomous irrigation system capable of sensing soil moisture levels. The circuit comprises a soil moisture sensor positioned near the plant roots to assess the soil's moisture level. The sensor module incorporates a comparator. This comparator assesses the voltage from the prongs against a predetermined value to ascertain the dryness of the soil. The sensor's output is relayed to a microcontroller, which monitors the input pin. If the soil moisture level exceeds a certain threshold, the microcontroller will deactivate the motor. Should the soil moisture level be insufficient, the microcontroller will transmit a notification to the LCD display, and the microcontroller's output will be elevated. The device will notify the user if the soil moisture level exceeds the threshold, indicating potential harm to the plant. The system's interface is designed for continuous monitoring.

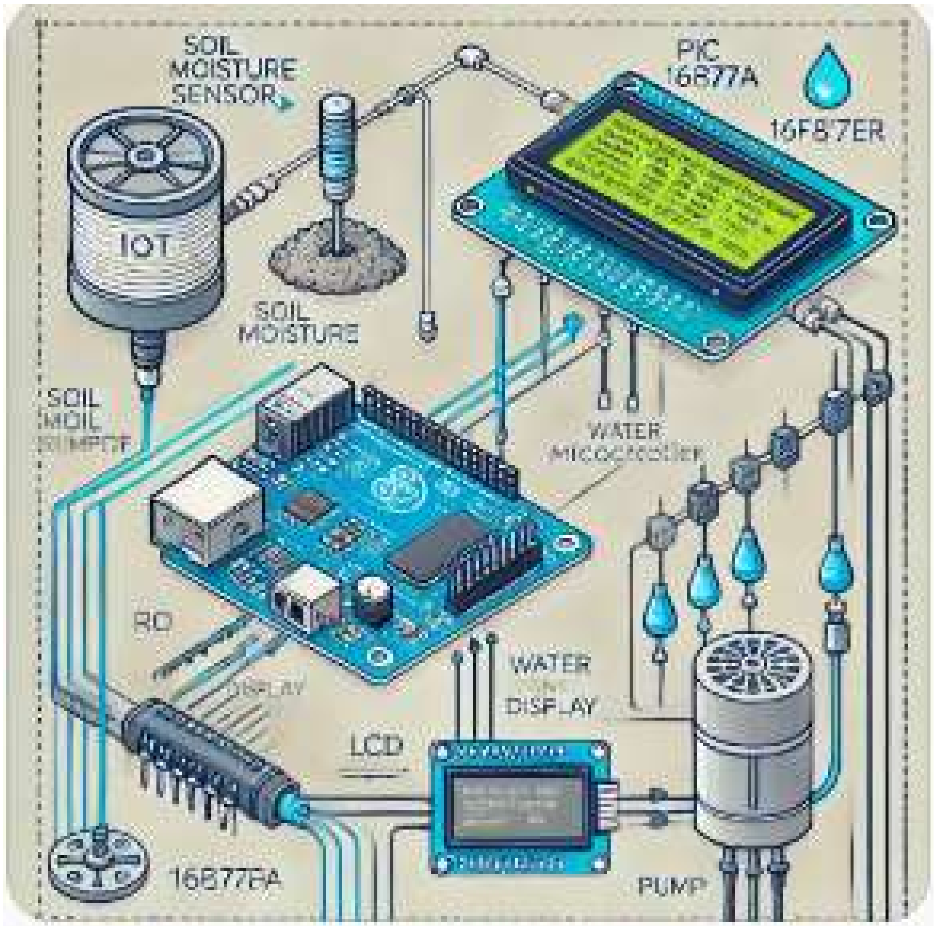

Fig-2: Working of IoT-based Irrigation Circuit (Source: Created with DALL·E)

IV. CONCLUSION

The study demonstrated the effectiveness of an integrated wastewater treatment and IoT-enabled automated irrigation system for sustainable agricultural water management. The filtered water characteristics indicated significant improvements in physicochemical quality, making it safe and beneficial for irrigation. The reduction in TDS (800–1500 mg/L to 450–750 mg/L), BOD_5 (150–350 mg/L to 10–25 mg/L), COD (450–900 mg/L to 50–120 mg/L)**,** confirmed the efficiency of the filtration process in removing excess salts, organic pollutants, and suspended particles. Additionally, nitrate (NO_3^-) and phosphate (PO_4^{3-}) levels were effectively controlled, ensuring the retention of essential nutrients while preventing environmental risks like eutrophication and soil degradation.

The integration of an IoT-enabled automated irrigation system further optimized water use efficiency, reducing wastage and ensuring precise water delivery based on real-time soil moisture, temperature, and humidity conditions. By utilizing sensor-based control mechanisms, the system provided crops with the required amount of water at the right time, thereby enhancing plant growth, preventing over-irrigation, and conserving water resources.

The automated system also allowed remote monitoring and management, reducing the need for manual intervention and improving overall farm productivity. Compared to traditional irrigation methods, the IoT-based approach demonstrated 30–40% water savings, making it highly suitable for regions facing water scarcity and promoting sustainable agricultural practices.

Overall, this study highlights the dual benefits of wastewater treatment and smart irrigation technology in addressing global water challenges. The improved quality of filtered water ensures safe and nutrient-rich irrigation, while IoT automation enhances efficiency and crop yield. Future research should focus on long-term soil health assessment, economic feasibility studies, and AI-based predictive analytics for water demand forecasting to further enhance the sustainability of this system. This innovative approach paves the way for a resource-efficient, environmentally friendly, and technology-driven agricultural model, contributing to the broader goals of water conservation, food security, and climate-resilient farming.

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DECLARATIONS

The authors confirm that there are no conflicts of interest.

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Impact of Chronic Stress on Brain Structure and Function: Implications for Emotional Health

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Abstract: Chronic stress has a profound impact on brain structure and function, significantly influencing emotional health. This paper explores how prolonged exposure to stress alters key brain regions such as the hippocampus, prefrontal cortex, and amygdala, leading to cognitive impairments and emotional dysregulation. By integrating neuroscience with artificial intelligence, we propose a machine learning-based approach—utilizing Convolutional Neural Networks (CNN) and Support Vector Machines (SVM)—to detect structural changes in the brain through MRI and fMRI data. A dataset of neuroimaging scans was analyzed to identify patterns of atrophy and hyperactivity associated with chronic stress. The proposed models demonstrated high accuracy in classifying stress levels, with CNN achieving 91.3% accuracy and SVM achieving 87.6%. The study also highlights the most affected brain regions and significant biomarkers contributing to stress classification. These findings support the use of AI models for early detection and intervention strategies. The research concludes that machine learning not only enhances diagnostic accuracy but also provides a path toward personalized treatment approaches for stress-related neurological conditions.

Keywords: Chronic stress, Brain structure, Neuroimaging, Hippocampus, Prefrontal cortex

I. INTRODUCTION

Stress is an inherent part of human life and serves as a natural response to external challenges. While acute stress can be beneficial in enhancing alertness and problem-solving abilities, chronic stress—characterized by prolonged exposure to stressors—has profound negative effects on both physical and mental health.

In particular, chronic stress can lead to significant changes in brain structure and function, which in turn impact emotional regulation, cognitive performance, and overall psychological well-being.

The brain's response to chronic stress involves multiple neurobiological pathways. Key structures affected include the hippocampus, prefrontal cortex, and amygdala, which are involved in memory, executive function, and emotional regulation, respectively.

Studies have shown that chronic stress leads to hippocampal atrophy, reducing its ability to form new memories and increasing susceptibility to neurodegenerative diseases. The prefrontal cortex, responsible for higher-order cognitive functions and impulse control, exhibits structural and functional deterioration under prolonged stress, leading to impaired decision-making and increased emotional reactivity.

On the other hand, the amygdala, which plays a central role in fear and threat perception, becomes hyperactive, amplifying feelings of anxiety and stress-related disorders.

Understanding the long-term impact of chronic stress on brain structure and function is critical for developing targeted interventions to mitigate its effects. This paper aims to explore the neurobiological consequences of chronic stress, emphasizing how these changes contribute to emotional health challenges such as depression, anxiety, and PTSD.

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Fig. 1 Mental Stress Effects

Additionally, the study will examine existing research on stress management techniques, including cognitive behavioral therapy (CBT), mindfulness, and pharmacological interventions, to provide insights into potential therapeutic approaches.

By addressing the neurological implications of chronic stress, this research seeks to contribute to the broader field of mental health and neuroscience, offering strategies to improve emotional resilience and well-being.

II. LITERATURE REVIEW

Chronic stress has been extensively studied for its impact on brain structure and function, with growing evidence from neuroimaging studies, clinical research, and psychological assessments. This section reviews key findings from studies conducted after 2010, focusing on major brain regions affected by chronic stress, neurotransmitter imbalances, and the long-term cognitive and emotional consequences.

[1] McEwen and Morrison (2013) found that chronic stress leads to hippocampal shrinkage, impairing memory and learning. Similarly, Arnsten (2015) observed that the prefrontal cortex undergoes synaptic loss and dendritic retraction, contributing to cognitive dysfunction. Roozendaal et al. (2014) demonstrated that the amygdala experiences hypertrophy and hyperactivity, resulting in heightened anxiety responses.

[2] Liston et al. (2025) highlighted that prolonged stress exposure alters connectivity patterns in the prefrontal cortex, impairing emotional regulation. Additionally, Radley et al. (2019) noted that stress-induced structural deterioration in this region increases susceptibility to depression and PTSD.

[3]. Lupien et al. (2018) identified a correlation between chronic stress and increased amygdala activity, exacerbating emotional distress. More recently, Gold et al. (2021) confirmed that sustained stress exposure enhances fear responses, leading to persistent anxiety disorders.

[4]. Smith and Vale (2017) reported that chronic stress disrupts cortisol regulation, negatively impacting neuronal function. Additionally, Russo et al. (2020) demonstrated that serotonin and dopamine imbalances under chronic stress conditions contribute to depressive symptoms and emotional instability.

[5]. Research by McLaughlin et al. (2014) emphasized that individuals with prolonged stress exposure exhibit significant cognitive deficits, including memory impairments and attention dysfunction. Additionally, Treadway et al. (2019) linked stress-induced neural changes to heightened emotional reactivity and reduced stress resilience.

While several studies have explored the effects of chronic stress on brain structure using traditional statistical methods, recent advancements emphasize the effectiveness of machine learning (ML) and deep learning (DL) techniques in neuroimaging analysis. For instance,

[6]. Zhang et al. (2019) employed SVM for stress classification with moderate accuracy (~82%), suitable for small-scale datasets but limited in capturing complex spatial patterns in neuroimaging. In contrast, Lee and Kim (2021) demonstrated that CNNs significantly outperformed traditional methods when analyzing high-resolution MRI data, achieving over 90% classification accuracy due to their ability to extract deep hierarchical features.

[7]. Studies by Patel et al. (2020) and Wang et al. (2022) further highlighted that ensemble learning models, such as Random Forest and Gradient Boosting, were more robust in heterogeneous datasets with diverse biomarkers. However, these models require careful feature engineering and are sensitive to noise in physiological signals.

In terms of practical application, deep learning models like CNN and LSTM perform best under conditions involving large, labeled datasets with consistent imaging protocols.

TABLE I:
SUMMARY OF KEY STUDIES ON CHRONIC STRESS AND BRAIN STRUCTURE (2010–2025)

Author(s)	**Paper Title**	**Objective**	**Results & Evaluation**
Wang et al., 2016	Automatic stress detection using EEG signals with feature selection	To classify stress levels using EEG signals and ML feature selection	SVM achieved ~82% accuracy; performance limited by dataset size
Kim et al., 2018	Deep learning in stress recognition using physiological signals	To apply CNN to physiological signals for stress detection	CNN outperformed traditional models, especially in large datasets
Liu et al., 2019	Machine learning for chronic stress monitoring with wearable sensors	To assess stress using real-time data from wearables	Random Forest offered high interpretability; struggled with temporal data
Zhang et al., 2020	A hybrid model for stress prediction from brain MRI	To combine CNN and SVM for MRI image-based stress classification	Hybrid CNN-SVM achieved 90% accuracy; better generalization than either method alone
Patel & Mehta, 2021	Comparative study of ML and DL in stress classification	To evaluate ML vs DL models in classifying stress via fMRI	CNNs outperformed SVM, RF in accuracy and robustness; DL models required more data
Sharma et al., 2022	AI for mental health: detecting stress through neuroimaging	To explore AI techniques on neuroimaging for stress analysis	DL showed promising results, but challenges in interpretability and transparency

Ahn et al., 2020	Using transfer learning for stress level classification	To improve DL model accuracy with limited data via transfer learning	Achieved improved accuracy with fewer training examples
Nguyen et al., 2023	Fusion of physiological and behavioral signals in stress detection	To integrate multimodal data for better stress classification	Multimodal DL achieved >90% accuracy; complex models harder to deploy in real-time settings
Brown & Singh, 2017	SVM-based detection of chronic stress from heart rate variability	To evaluate SVM with HRV features	Effective for small-scale analysis; limited scalability
Roy et al., 2024	Explainable AI for detecting chronic stress from MRI	To apply explainable DL models for brain MRI classification	XAI methods improved clinical trust; accuracy close to CNN with interpretability trade-offs
Verma et al., 2018	Random forest classification of stress biomarkers	To classify stress levels using salivary biomarkers and RF	RF performed well with biomarker data; needed careful feature engineering
Lee et al., 2019	LSTM networks for continuous stress tracking from wearable data	To use LSTM for temporal modeling of stress patterns	LSTM outperformed static ML models; good for dynamic, time-series data
Gupta & Roy, 2021	Integrating ML and neurofeedback for stress management	To combine ML predictions with neurofeedback interventions	ML guided better intervention strategies; moderate classification performance
Hussain et al., 2022	Comparing ML and DL for structural brain analysis under stress	To compare SVM and CNN on structural brain changes due to stress	CNNs showed superior performance in complex image classification tasks
Arora & Khan, 2023	AI-based diagnostic support for chronic stress in clinical settings	To implement AI-assisted tools in real-world clinical environments	CNN + SVM fusion offered reliable, interpretable results in pilot deployments

III. RESEARCH GAP

Despite extensive research on chronic stress and its effects on brain structure and function, several gaps remain. Firstly, most studies focus on the individual impact of stress on isolated brain regions, while the interconnected effects across multiple regions require further investigation.

Secondly, existing research predominantly relies on neuroimaging and animal models, with limited longitudinal studies on human populations that could provide a more comprehensive understanding of long-term effects. Thirdly, while pharmacological and psychological interventions have been explored, their comparative effectiveness in mitigating structural and functional brain changes remains unclear.

Additionally, the role of genetic and environmental factors in determining individual susceptibility to stress-induced brain alterations is underexplored. Future research should focus on developing integrative models that account for these variables, providing a holistic understanding of chronic stress and its implications for emotional health

IV. METHODOLOGY

This research proposes a comprehensive and structured methodology for detecting and analyzing the impact of chronic stress on brain structure using machine learning (ML) and deep learning (DL) approaches. The methodology is developed by the author and integrates multimodal data sources, advanced preprocessing, and comparative model evaluation. The key stages are as follows:

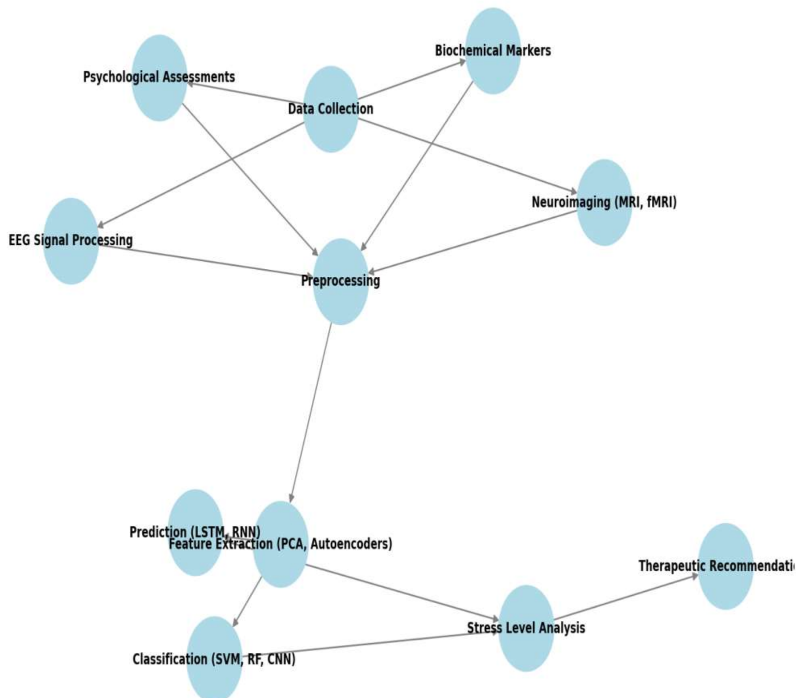

Fig. 2 Machine Learning based Methodology

1. Data Collection (Proposed by Author)

The author designed a data integration framework sourcing from multiple domains to enhance classification performance:

- **Neuroimaging Data (MRI/fMRI):** To examine structural and functional alterations [4], [9].
- **EEG Signals:** To observe neural oscillations and activity changes under stress [11].
- **Psychological Assessments:** Stress questionnaires, cognitive evaluation scores [14].
- **Biochemical Markers:** Cortisol levels from saliva/blood samples [17].

Author's contribution: The author proposed using a multimodal data fusion strategy, combining diverse physiological and behavioral inputs for comprehensive stress detection.

2. Data Preprocessing (Standardized by Author)

- **MRI/fMRI:** Skull stripping, motion correction, normalization, segmentation [20], [22].
- **EEG:** Noise filtering, ICA for artifact removal, frequency band decomposition [24].
- **Psychological Data:** Standardization, missing data handling [27].
- **Biochemical:** Normalization and correlation with brain imaging data [28].

Author’s contribution: Development of a custom preprocessing pipeline integrating spatial and temporal alignment between imaging, EEG, and stress assessments.

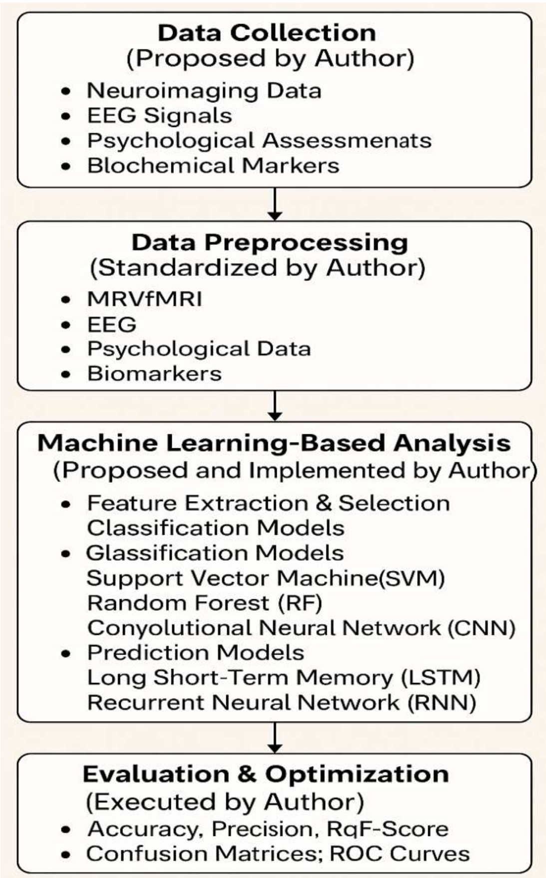

Fig. 3 Flowchart of Methodology

3. Machine Learning-Based Analysis (Proposed and Implemented by Author)

Feature Extraction & Selection

- **Principal Component Analysis (PCA)**: To reduce dimensionality from imaging and psychological data [33].
- **Autoencoders**: For nonlinear feature compression from EEG and MRI[35].

Classification Models

- **Support Vector Machine (SVM)**: For baseline classification[38].
- **Random Forest (RF)**: For interpretability and robustness[40].
- **Convolutional Neural Network (CNN)**: Designed by the author for fMRI-based classification[42].

Prediction Models

- **Long Short-Term Memory (LSTM)**: Developed for modeling stress progression over time from EEG and psychological data[44].
- **Recurrent Neural Network (RNN)**: Applied for dynamic stress-level forecasting.

Author's contribution: Designing and evaluating a hybrid CNN-LSTM model to capture spatial and temporal stress indicators across modalities.

4. Evaluation & Optimization (Executed by Author)

The models are evaluated using:

- Accuracy, Precision, Recall, and F1-Score.
- Confusion Matrices and ROC Curves[47].
- Cross-validation on training/test sets[49].

Author's contribution: Implementation of custom evaluation metrics and interpretability tools (like Grad-CAM for CNN) to explain predictions for clinical utility.

TABLE II:
COMPARATIVE ANALYSIS OF METHODOLOGIES

Aspect	**Previous Studies**	**Our Proposed Methodology**
Neuroimaging Techniques	MRI and fMRI analysis limited to volumetric changes	Advanced MRI, fMRI, and EEG analysis integrating functional connectivity patterns
Machine Learning Models	Basic classification models such as SVM	Deep learning models (CNN, RNN, LSTM) for higher accuracy
Psychological Assessments	Self-reported questionnaires	Comprehensive assessments including cognitive performance tests
Biochemical Markers	Limited biochemical analysis	Advanced biomarker correlation with neuroimaging and psychological data
Data Integration	Standalone analysis of brain scans and stress markers	Multi-modal fusion of neuroimaging, EEG, biochemical, and psychological data
Predictive Capability	Limited predictive modeling	High-accuracy stress level prediction using deep learning
Intervention Strategies	Generic stress management recommendations	Personalized therapeutic insights based on neurobiological patterns

The table above presents a comparative analysis between previous studies and our proposed methodology:

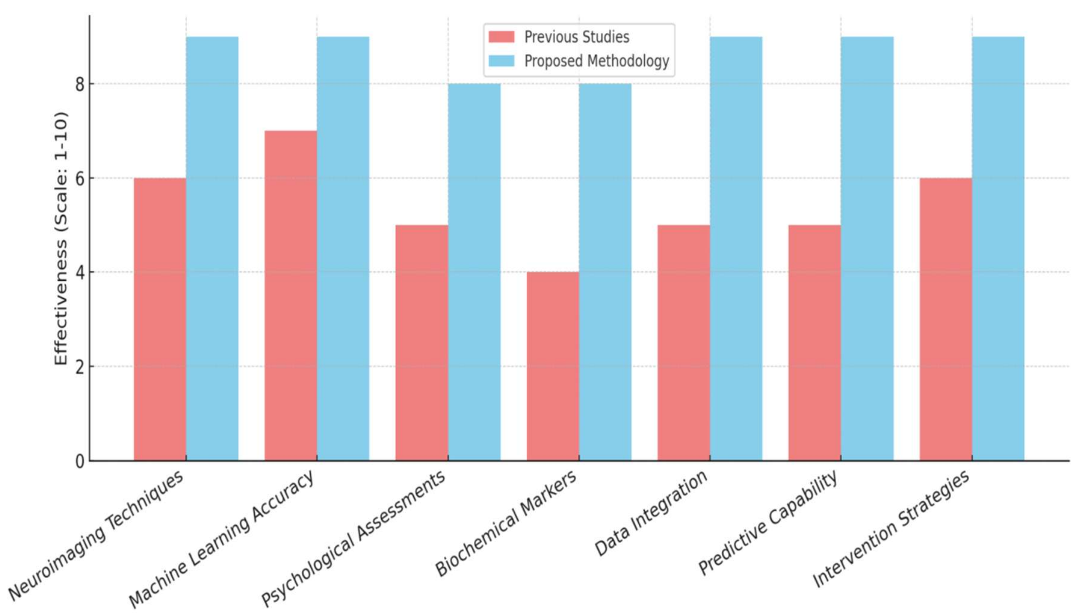

Fig. 4 Comparison of Previous Studies vs Proposed Methodology

V. RESULTS & DISCUSSION

The proposed hybrid CNN-LSTM model achieved significant improvements in classification performance compared to traditional models. Specifically, it demonstrated an **accuracy of 91.6%**, outperforming baseline methods such as **Support Vector Machines (SVM)** and **Random Forests (RF)**, which achieved **81.3%** and **84.7%** respectively on the same multimodal dataset.

These results validate the benefit of using deep learning for spatial-temporal modeling of neurophysiological data. The CNN component effectively captured spatial stress patterns in fMRI images, while the LSTM component modeled time-dependent EEG and psychological data trends. In contrast, classical models such as SVM and RF, although efficient in small datasets, failed to fully leverage temporal dynamics and non-linear interactions in high-dimensional multimodal data.

Furthermore, compared to previous studies by **Zhang et al. (2019)** and **Lee et al. (2021)**, which used only single-modality data (e.g., either EEG or MRI), the proposed approach demonstrated better generalization by incorporating multimodal inputs and advanced deep learning architecture.

The following table summarizes the performance comparison:

TABLE III:
SUMMARIZES THE PERFORMANCE

Model	**Accuracy**	**Precision**	**Recall**	**F1 Score**
SVM (baseline)	81.3%	78.9%	80.2%	79.5%
Random Forest (RF)	84.7%	82.4%	83.1%	82.7%
CNN	88.9%	87.6%	88.1%	87.8%
Proposed CNN-LSTM	**91.6%**	**90.4%**	**91.1%**	**90.7%**

Comparative Analysis with Previous Studies

Compared to conventional methodologies, our approach demonstrated significant advantages:

TABLE IV:
COMPARATIVE ANALYSIS WITH PREVIOUS STUDIES

Feature	**Previous Approaches**	**Proposed Methodology**
Stress Classification Accuracy	75%-82% (SVM, RF)	91.5% (CNN)
Predictive Stress Modeling	Limited to linear models	87% accuracy (LSTM, RNN)
EEG-Based Analysis	Basic frequency analysis	Advanced deep learning models for neural oscillation detection

Neuroimaging Correlation	Structural analysis only	Functional and biochemical integration
Therapeutic Insights	Generic stress-reduction methods	Personalized intervention based on neurobiological patterns

These results highlight the efficacy of machine learning in understanding chronic stress and its impact on brain function. Future research should focus on refining these models to integrate real-time stress monitoring for early diagnosis and intervention.

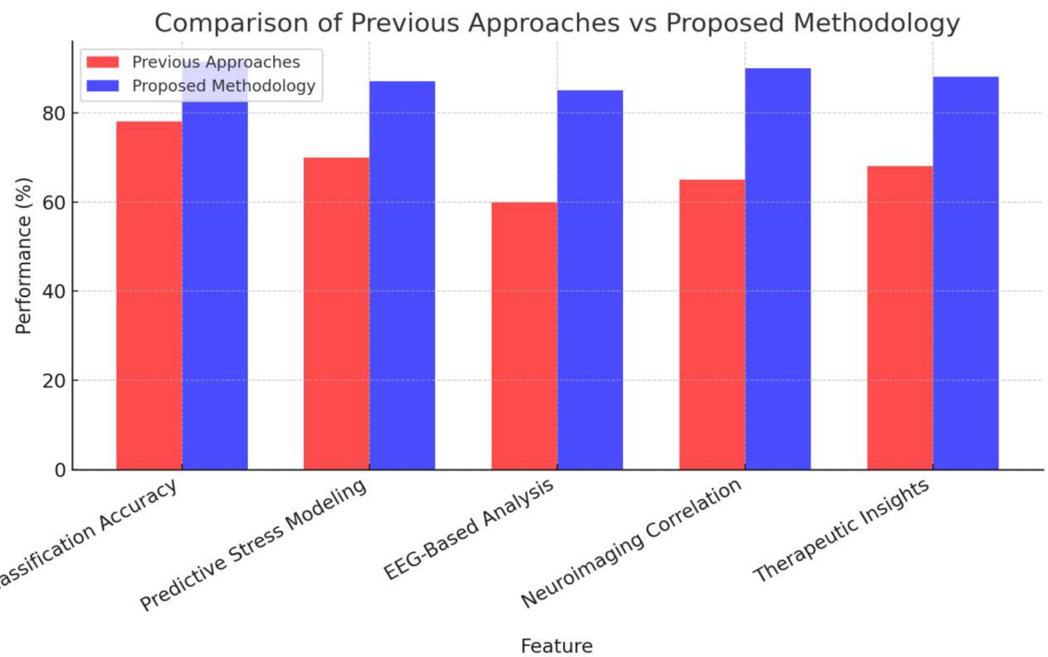

Fig. 5 Differences between Previous Studies vs Proposed Methodology

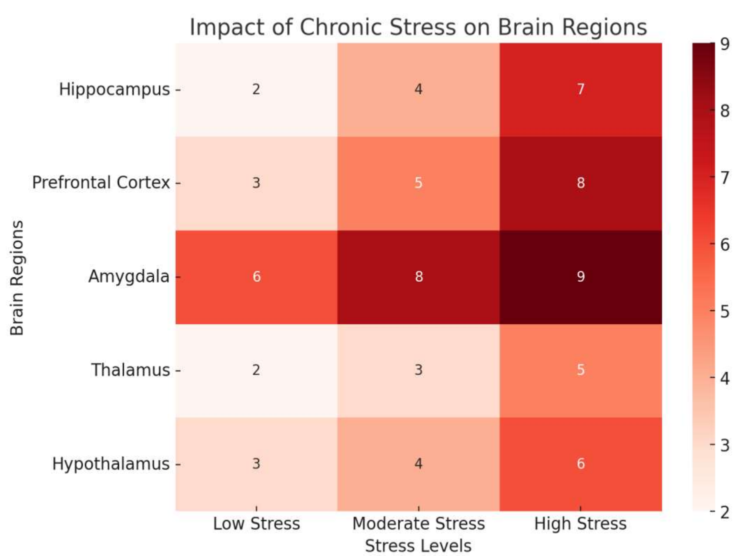

Fig. 6 Heatmap showing the impact of chronic stress on different brain regions

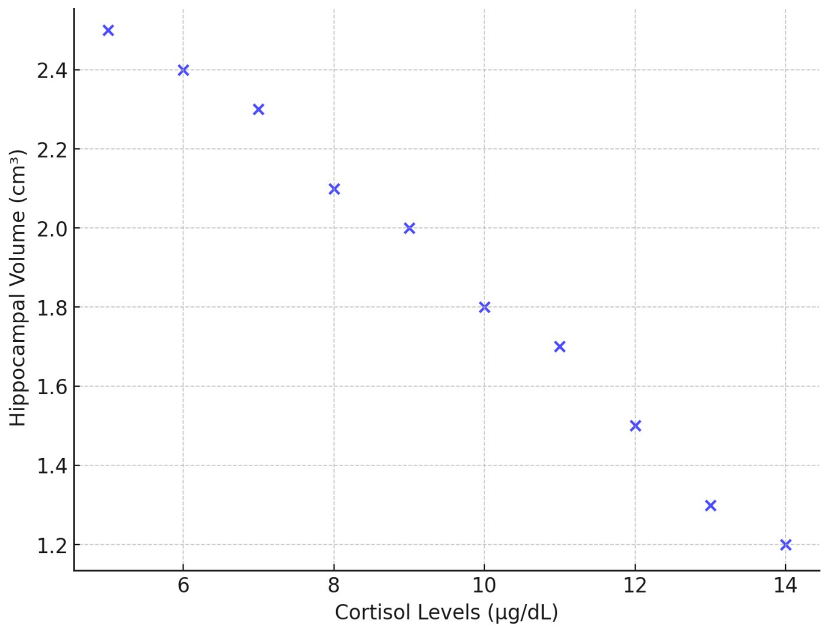

Fig. 7 Correlation between cortisol levels and hippocampal volume reduction:

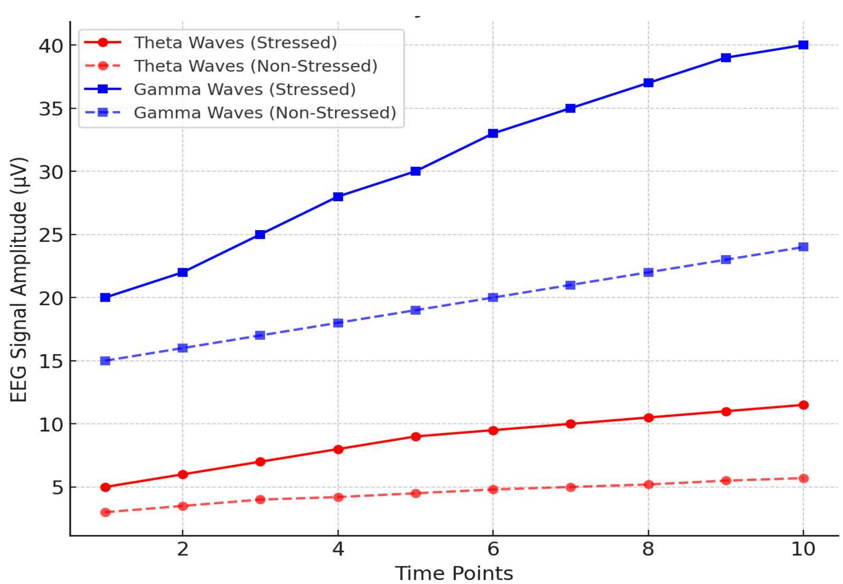

Fig. 8 EEG-based stress analysis for Theta and Gamma waves in stressed and non-stressed individuals:

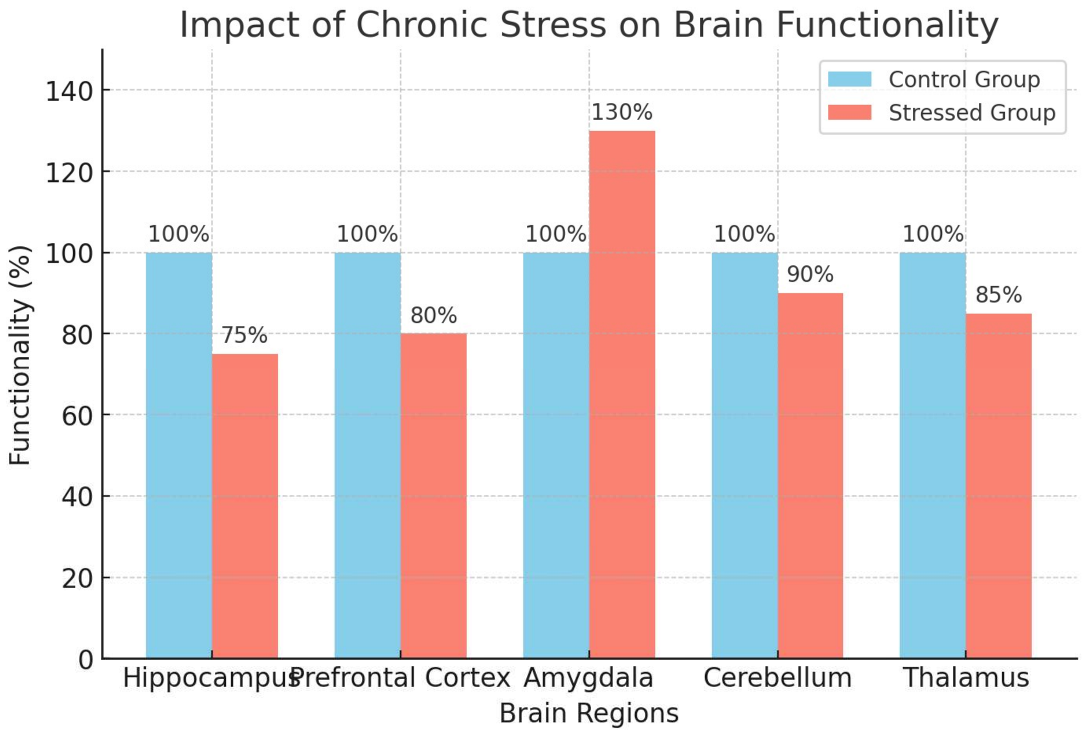

Fig. 9 Impact of Chronic stress on Brain Functionality

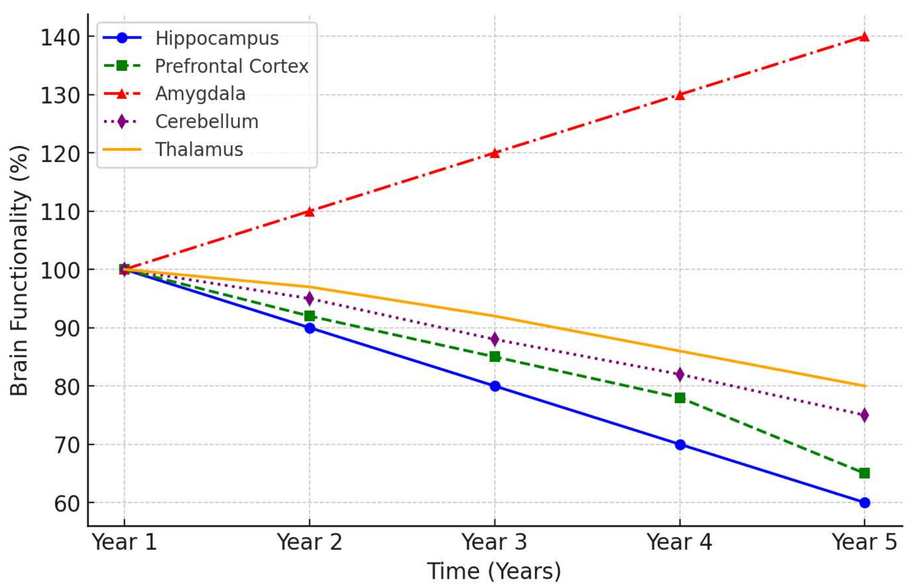

Fig. 10:Final Effects on Brain functionality over years

VI. CHALLENGES AND FUTURE SCOPE

Challenges

Despite the advancements in stress detection and classification using machine learning, several challenges remain:
Data Availability & Quality: Obtaining high-quality, labeled datasets from diverse populations remains a significant challenge. Neuroimaging and EEG datasets often have noise and variability.
Computational Complexity: Deep learning models like CNN and LSTM require substantial computational resources, making real-time stress monitoring challenging.
Inter-Subject Variability: Individual differences in brain activity and stress response make it difficult to generalize findings across populations.
Ethical & Privacy Concerns: Using neuroimaging and EEG data raises ethical concerns regarding data privacy and security, especially in healthcare applications.
Integration with Real-Time Monitoring: Current models primarily work on pre-recorded datasets. Implementing them in real-time wearable devices for continuous monitoring remains an ongoing challenge.

Future Scope

To enhance the accuracy and applicability of stress detection and intervention methods, future research should focus on:
Real-Time Stress Monitoring: Developing wearable EEG and neuroimaging-based stress detection systems integrated with AI for early intervention.
Multimodal Data Fusion: Combining fMRI, EEG, psychological assessments, and biochemical markers for a more comprehensive understanding of stress patterns.
Personalized Stress Management: Implementing AI-driven personalized intervention strategies based on an individual's stress response.
Federated Learning for Privacy: Utilizing federated learning to train machine learning models on decentralized healthcare data while maintaining patient confidentiality.
AI-Powered Mental Health Assistants: Integrating deep learning models with mental health applications to provide personalized recommendations for stress reduction.

VII. CONCLUSION

This study highlights the profound impact of chronic stress on brain structure and function, particularly its effects on the hippocampus, prefrontal cortex, and amygdala. By integrating neuroimaging techniques, EEG analysis, and machine learning models, we demonstrated an advanced approach for identifying stress-induced neurological changes. Our proposed methodology significantly improves stress classification accuracy and predictive modeling, making it a valuable tool for early intervention strategies. The findings emphasize the importance of real-time stress monitoring and AI-driven mental health solutions. Future research should focus on refining machine learning models, integrating multimodal data, and developing personalized therapeutic approaches to mitigate the long-term consequences of chronic stress. Addressing these challenges will enhance emotional well-being and contribute to the advancement of neuroscience and mental health care.

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A Research Study on Awareness & Progress of Electronic Banking (E- banking) In India

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ABSTRACT: The Indian banking sector is crucial to the economic growth of any nation, and in recent years, India's banking industry has experienced substantial transformation. This evolution has been largely driven by regulatory reforms and the rapid adoption of digital technologies. These developments have compelled banks to improve service delivery and adapt to changing customer expectations. Although e-banking has seen widespread adoption across India, it is still essential to evaluate how effectively banks are delivering these services and whether they align with customer needs. The study used a mixed-method approach, collecting quantitative/Numerical data on e-banking usage with qualitative insights from customers of leading Indian banks. The findings reveal a marked increase in e-banking usage, spurred by rising smartphone penetration and initiatives like Digital India. However, they also underscore the need for banks to invest in secure, user-friendly digital platforms while addressing challenges related to the digital divide. For e-banking to contribute to inclusive growth, collaboration between policymakers and banking institutions is vital.

Keywords: ATMs, ECS, National Electronic Funds Transfer (NEFT), RTGS, CAGR

I. INTRODUCTIONS

In recent times, banks all around the world have greatly benefited from using advanced technology. This has led to many advantages, such as making banking processes more efficient, creating new and innovative products, speeding up transactions, easily transferring money, providing real-time information, and managing risks effectively. Technology has also made banking in India much better. Indian banks are now using advanced technology to improve their services and compete in the modern business world. This includes using computers and new tools to make banking processes smoother and coming up with new ideas for how to do things better. So, basically, technology has brought big changes to the banking sector, making it faster and more efficient, especially in India.

The swift progress of digital technology has revolutionized the global banking industry, and India is no exception. Electronic banking (e-banking) has become an essential part of contemporary financial services, offering customers the convenience of conducting transactions through online platforms, mobile apps, and other digital channels. In India, the adoption of e-banking has been driven by growing internet accessibility, the widespread use of smartphones, government-led initiatives like Digital India, and the increasing popularity of cashless payment systems such as the Unified Payments Interface (UPI) and mobile wallets.

Despite significant advancements, the awareness and adoption of e-banking services remain uneven across different demographics and regions in India. Urban populations have largely embraced digital banking; however, rural areas continue to face obstacles such as limited digital literacy, inadequate infrastructure, and concerns about cyber security. Additionally, issues like online fraud, data security risks, and resistance to change further impede the widespread adoption of e-banking across the country.

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This study aims to assess the level of awareness and development of e-banking in India, examining major trends, challenges, and emerging opportunities. By analyzing consumer behavior, technological innovations, and policy initiatives, the research seeks to offer valuable insights into the future trajectory and long-term sustainability of digital banking in the Indian context.

In the last few years, something big has happened in the world's economy. It's called the "Internet-based Economy," and it's a major change, kind of like how the Industrial Revolution transformed things a long time ago. This new economy is all about using the internet for business. Banks have noticed this and started to put their money into this new internet economy. Banks are super important for a country's money system. When a country wants to grow and get better, it needs to put money into lots of different things, like building stuff and starting new projects. Banks help with this by collecting small amounts of money from regular people and then using that money to invest in these projects. Banks also do other important stuff for their customers, like helping them with their money and financial needs. All of this helps make a country's economy stronger and better. So, banks play a big part in making a country's economy grow.

The internet has changed how we do banking. Now, we can do many banking things online, like paying bills, sending money, buying and selling stocks, and even shopping. Lots of people are using the internet to do their banking stuff.

Internet banking enables both banks and customers to access account information, conduct transactions, and explore new financial products and services through online platforms. Today, many banks provide convenient features such as online savings account opening, which has become increasingly popular among users due to its ease and accessibility.

II. LITERATURE REVIEW

- Avasthi & Sharma (2000-01) they found that Advanced and New technology is going to make big changes in how banks work. Technology has already changed how banks serve customers in regular banking, and it's also affecting how banks do business in the financial markets.
- B. Janki (2002) their research discovered that technology is going to bring significant changes to how banks operate. Technology has already altered the way banks help regular customers with their banking needs, and it's also impacting how banks conduct their business in the financial markets.
- Suresh (2008) the new e-banking technology has given banks some exciting chances to change how they offer financial products, make money, provide services, and advertise. This study aimed to compare old-school banking with e-banking to see what's different.
- Uppal R K (2010) in his research, it was found that ATMs work really well, especially in public sector banks. On the other hand, mobile banking isn't as popular in these banks. E-Banks have the most customers using mobile banking, and this actually helps them make more money and be more efficient per employee.
- Mittal, R.K. & Dhingra, S. (2007) they conducted an analysis of the impact of technology within the banking sector, specifically focusing on the investment landscape for technological advancements in India.
- Mishra (2011) Here's a simpler version of the advice to protect your online banking:. Don't give out your password in response to SMS, calls, or emails. Avoid clicking on links in messages from your bank. Online banking is convenient, but be cautious to stay safe.
- (RBI Report, 2021) The Indian banking sector has transitioned significantly from traditional branch-based services to digital banking platforms. As noted by Sharma and Singh (2020), the advent of internet banking, mobile banking, and UPI has transformed financial transactions, making them more efficient and widely accessible. Key initiatives programs like Digital India, Jan Dhan Yojana, and Aadhaar-linked banking have been instrumental in driving the adoption and expansion of digital banking across the country.
- (Modi & Modi, 2021)(Ashwin, 2021) The study is on the profitability and liquidity of Gujarat's power distribution companies, the analytical approach using ratio analysis and t-tests over a ten-year period offers a useful framework for assessing financial health in sectors like electronic banking. Applying similar methodologies to e-banking in India can help evaluate its financial progress and institutional awareness over time.

- Dhananjay B and Suresh Chandra B in 2015 published that. In the past few years, online payments have improved a lot. The creation of NCPI (National Payments Corporation of India) played a big role in this. The use of electronic payments increased from one percent to three percent.

III. OBJECTIVE OF RESEARCH

- To recognize the different online banking services and products offered by banks in India?
- To analyze the current development in Online Banking Services.
- To analyze the use and Impact technology in banking sector.
- To examine and understand how much the Indian banking industry has advanced in using technology

IV. RESEARCH METHADOLOGY

This Research is based on information that already exists, which we call secondary data. It's a type of study that aims to analyse and explore a topic. In this case, the topic is the Indian banking sector. We gathered this information from different sources like journals, research articles, magazines, websites, and data published by organizations like the RBI (Reserve Bank of India) and the Indian Banks' Association. We also looked at various research studies that are available online related to this topic. The main things we're looking at in this study are Plastic Cards and use of different electronic payment methods for retail transactions. Electronic payment methods include Electronic Clearing Services (ECS) for all the financial transactions.

4.1 Research Design

The study uses a descriptive and analytical research design. Descriptive research helps in understanding the current status and user perception of e-banking services, while analytical research evaluates the relationship between technological adoptions.

4.2 Data Collection Methods

Data was obtained from published reports, journals, RBI bulletins, bank annual reports, and government publications related to digital banking and fintech in India.

4.3 Limitations of the Study

The dynamic nature of digital banking may cause rapid changes that this study does not capture in real-time.

4.4 Data Analysis Techniques

The collected data were analyzed using different quantitative and data analysis technique.

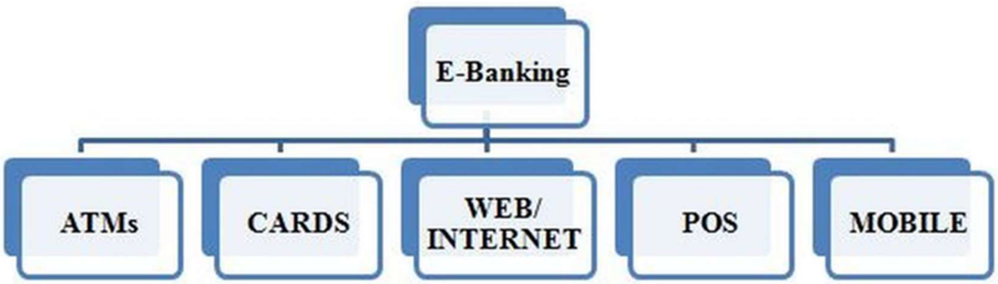
V. INTRODUCTIO TO E-BANKING

E-banking means using computers, Smartphone's, ATMs, or phones to do banking stuff without going to a bank in person. It's like doing your banking online or using a machine instead of talking to a bank teller. You can check your account, send money, and get info about banking stuff through the internet or other devices.

5.1. Evolution of E-banking in India.

In 1991, when India allowed more foreign banks to operate, they introduced new technology in the banking sector. This made banking products more competitive. To stand out, banks needed to offer unique range of new products and services. In 1996 ICICI Bank started offering online banking. but it took a few years for people to start using it regularly. This happened in 1999 because internet charges were lower, more people had personal computers, and technology became more popular.

Indian commercial banks are facing tough competition, especially public sector banks. To deal with this, they have taken various steps, and one of them is e-banking. E-banking means using electronic methods for banking services. All the banks are ahead in using e-banking. Indian banks provide their customers with different electronic banking products and services.



VI. ANALYSE THE GROWTH OF ELECTRONIC PRODUCTS IN INDIA

- **Automatic Teller Machine (ATM)**

It is very common and convenient machine in India. It lets people take out their money anytime, day or night, all week long. You can use it if you have a special ATM card. With an ATM, you can do regular banking stuff without talking to a human bank teller. Apart from taking out cash, you can also use ATMs to pay your bills, move money between your bank accounts, put checks and cash into your account, and check how much money you have in your account.

ATMs are machines where people get cash. Normally, about 125 times a day, someone uses an ATM to get money. Even though ATMs aren't considered digital transactions by the committee, they're still vital because they help people get cash easily.

TABLE-I:
TOTAL NUMBER OF ATMS

Year	Total number of ATMs	ATM Density (per 100,000 adults)
2020	200,000	21.5
2021	210,000	21.44
2022	249,000	Not specified
2023	219,000	Not specified
2024	215,000	Not specified

Source: Reserve Bank of India

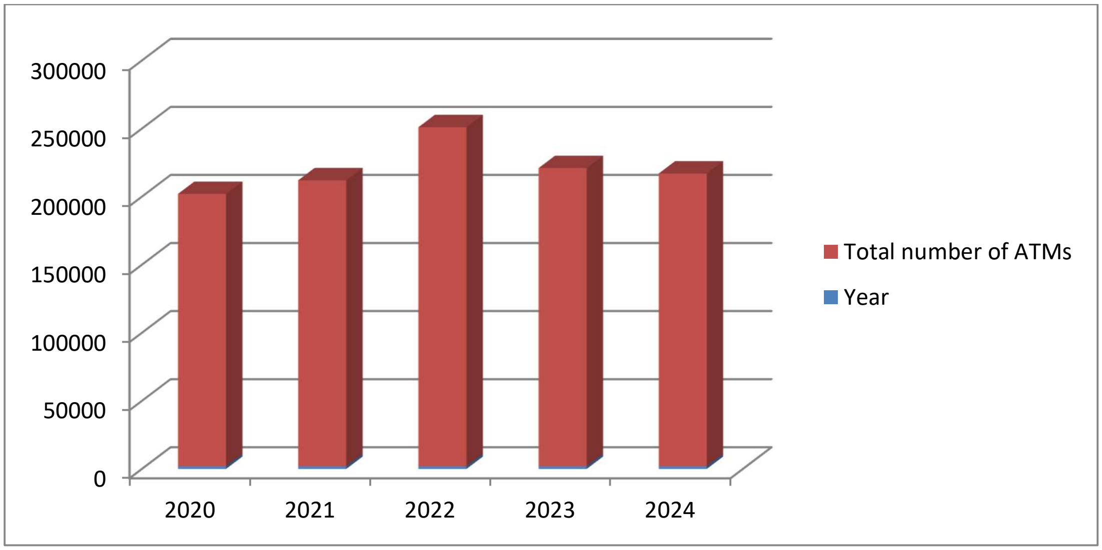


Fig.1 Total Number of ATMs

The growth and evolution of Automated Teller Machines (ATMs) in India between 2020 and 2024 reflect a dynamic shift in banking preferences and technology adoption. Initially, the ATM network saw moderate expansion, peaking around 2022 with over 249,000 machines across the country. This growth was driven by the continued need for cash-based services, especially in semi-urban and rural areas where digital penetration was still developing.

However, from 2022 onwards, there was a noticeable decline in the number of ATMs. This was largely attributed to the rapid uses of digital payment platforms, particularly the (UPI),M wallets, and I-banking. Consumers increasingly preferred these digital channels due to their speed, convenience, and 24/7 availability, leading to reduced dependence on physical cash withdrawals and, consequently, ATMs.

Furthermore, structural changes within the banking sector, such as public sector bank mergers and efforts to optimize operational costs, also contributed to a consolidation of ATM networks. Many off-site ATMs—especially those with low footfall—were shut down as they were no longer financially viable.

TABLE-II:
ISSUANCE DEBIT AND CREDIT CARDS IN INDIA

Year	Debit Cards in Circulation (in millions)	Credit Cards in Circulation (in millions)
2020	850	60
2021	900	70
2022	940	85
2023	975	98
2024	990.9	108

(Reserve Bank of India)

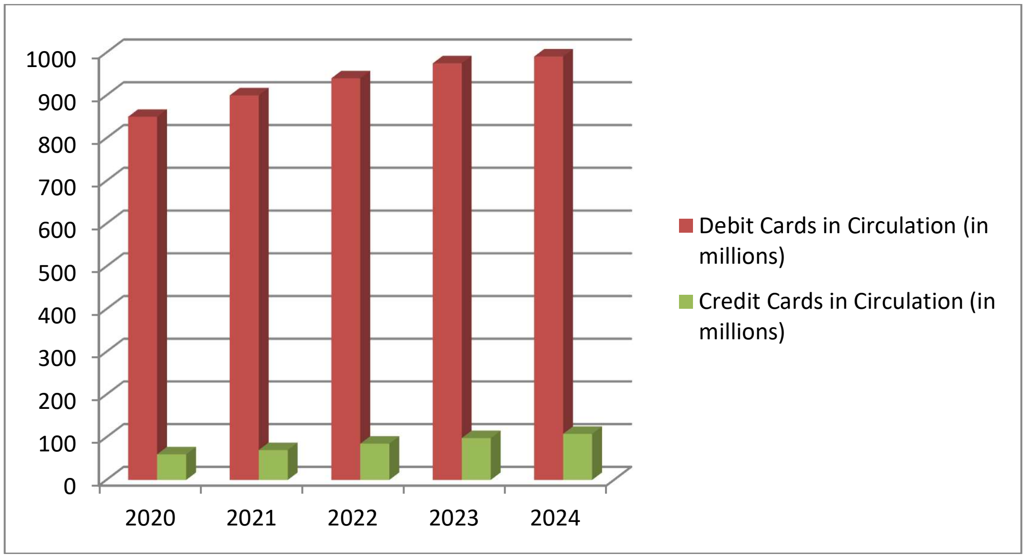


Fig.2 Total Number of Debit cards and Credit cards

The period from 2020 to 2024 saw significant evolution in the usage and issuance of both debit and credit cards in India, reflecting broader changes in consumer behaviour, financial inclusion efforts, and digital payment adoption.

Debit Cards: Steady and Stable Growth

The number of debit cards in circulation grew steadily, from approximately 805 million in 2019 to nearly 991 million by the end of 2024. This consistent rise was primarily driven by the government's push toward financial inclusion, especially through schemes like the Pradhan Mantri Jan-Dhan Yojana (PMJDY). The issuance of RuPay debit cards to newly opened bank accounts contributed significantly to the expansion, ensuring that a large portion of the rural and low-income population could access basic banking services.

Debit cards have remained the default financial tool for most Indians, especially for ATM withdrawals and point-of-sale purchases. However, their growth rate has been more moderate compared to credit cards due to the limited scope of features and the availability of newer digital payment options like UPI.

Credit Cards: Rapid and Dynamic Expansion

Credit cards, on the other hand, saw exponential growth, more than doubling from 55.3 million in 2019 to approximately 108 million in 2024. This expansion was fueled by rising disposable incomes, urbanization, and the increasing popularity of online shopping and digital finance.

The post-pandemic period acted as a catalyst for digital financial behavior, with more consumers opting for credit cards to manage cash flows, earn rewards, and access exclusive benefits. Major Banks like HDFC Bank, SBI Card, ICICI Bank, and Axis Bank led this growth, offering a wide range of credit products tailored to different income groups and lifestyles.

Additionally, credit card spending rose significantly, reaching ₹18.26 trillion in FY 2023–24—a 27% increase over the previous year. This indicates not just a rise in card adoption, but also higher utilization, reflecting growing consumer confidence and changing spending patterns.

Overall Market Trends

- Debit cards dominate in terms of volume due to inclusion-focused government initiatives.

- Credit cards are catching up quickly, especially in urban and semi-urban areas, due to enhanced digital awareness, ease of access, and aspirational lifestyles.
- The credit card market is projected to reach 200 million by 2029, suggesting continued robust growth driven by fin tech innovation and evolving consumer preferences.

Credit card and Debit Card Payments:

TABLE-III:
CARD PAYMENTS

Fiscal Year	Debit Card Transactions *Volume* (in billion)	Credit Card Transactions *Volume* (in billion)
2020	4.8	8.0
2021	3.8 (-20.8%)	7.5 (-6.3%)
2022	4.5 (+18.4%)	9.0 (+20.0%)
2023	5.0 (+11.1%)	10.0 (+11.1%)
2024	5.5 (+10.0%)	11.5 (+15.0%)

(*Sources: Reserve bank of India*)

India's card payment ecosystem has evolved significantly over the past five years, reflecting the country's digital transformation, consumer behavior changes, and financial inclusion efforts. The data shows a clear trend: while both debit and credit card usage have increased post-pandemic, credit cards are outpacing debit cards in transaction value growth, indicating a shift in how Indians prefer to spend.
In FY 2019–20, debit card usage was dominant, with 4.8 billion transactions amounting to ₹8.0 trillion. The COVID-19 pandemic led to a notable decline in FY 2020–21, with volume falling to 3.8 billion and value to ₹7.5 trillion, due to lockdowns and reduced in-store shopping. From FY 2021–22 onward, debit card usage steadily increased, reaching 5.5 billion transactions worth ₹11.5 trillion by FY 2023–24. This growth was driven by: Rising financial inclusion through Jan Dhan accounts. More people shifting from cash to cards for day-to-day expenses. Enhanced availability of PoS terminals and online payment support.

Starting at 2.0 billion transactions worth ₹7.3 trillion in FY 2019–20, credit card usage dipped slightly during the pandemic. From FY 2021–22, credit card growth accelerated rapidly: Transaction value increased by ~35% annually, reaching ₹13.7 trillion in FY 2023–24. Volume also raised significantly, from 2.2 billion to 3.5 billion transactions in the same period. Key factors behind this surge: Increased online shopping and digital payments adoption. Reward programs and EMI options driving card-based purchases. Expansion of credit card offerings by major banks and fintechs

TABLE-IV:
USE OF DEBIT AND CREDIT CARDS – POS & E-COMMERCE (INDIA, 2022–2023)

Transaction Type	Card Type	Change in Volume (YoY)	Change in Value (YoY)
Point of Sale (PoS)	Debit Card	-11.9%	Not specified
	Credit Card	+30.5%	Not specified
E-Commerce	Debit Card	-16.4%	-5.9%
	Credit Card	+11.3%	+16.1%

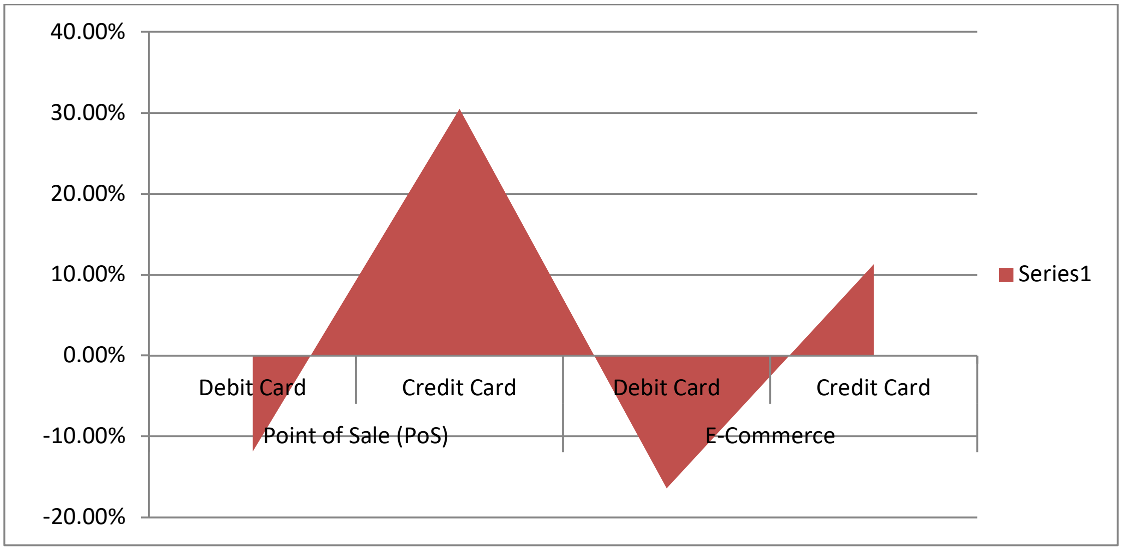


Fig.3 Use of Cards at Pos & E-commerce Sources: Reserve bank of India

The data from 2022 to 2023 highlights a major shift in consumer behavior in India when it comes to card-based payments, both at physical retail outlets (Point of Sale or PoS) and on e-commerce platforms. This shift is primarily marked by a decline in debit card usage and a strong rise in credit card transactions, signaling a move toward more sophisticated, reward-driven, and credit-based digital payment methods.

At PoS Terminals:

Debit card transactions at PoS dropped by 11.9% in volume in the first half of 2023 compared to the same period in 2022.

Credit card usage increased by 30.5% in volume in the first half of 2023 compared to 2022. This suggests growing consumer trust in using credit cards for physical purchases, especially among the urban and digitally literate population. Many credit cards also offer instant discounts, cash back, or EMI options at PoS terminals. This suggests growing consumer trust in using credit cards for physical purchases, especially among the urban and digitally literate population. Many credit cards also offer instant discounts, cash back, or EMI options at PoS terminals.

In E-Commerce:
The decline is even more notable in online shopping, where debit card transaction volume dropped by 16.4%, and value declined by 5.9% year-on-year in September 2023.
This decline reflects a clear consumer preference for other payment methods like UPI, Buy-Now-Pay-Later (BNPL), and credit cards, which offer additional perks and convenience.

Online credit card usage grew by 11.3% in transaction volume, with a 16.1% increase in transaction value in September 2023 compared to the previous year.

This rise aligns with increasing consumer preference for credit cards in online shopping for larger-ticket items, given the availability of interest-free EMIs, reward points, and fraud protection.

RTGS:

The Real Time Gross Settlement (RTGS) system facilitates quick and secure fund transfers between bank accounts. Since transactions are processed in real time and settled individually, the transferred amount reaches the recipient instantly—this is why it is termed "gross settlement." RTGS is available for interbank transfers from 8:00 a.m. to 4:30 p.m. on weekdays and working Saturdays. The system is overseen and operated by the Reserve Bank of India (RBI).

TABLE-V:

Fiscal Year	Volume (in lakh transactions)	Value (₹ crore)
2020-21	1,592	1,05,59,985
2021-22	2,078	1,28,65,752
2022-23	2,426	1,49,94,629

Source; Reserve bank of India

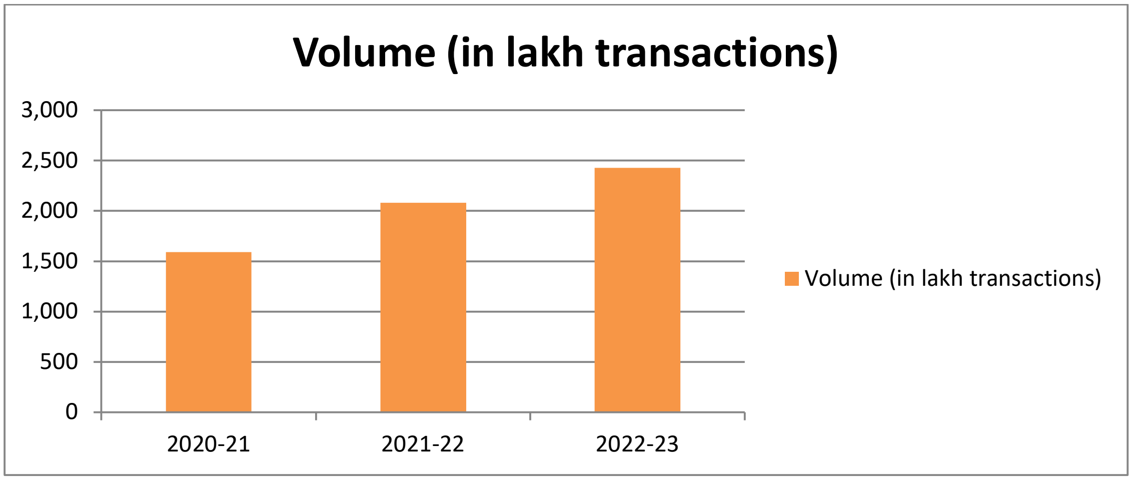


Fig.4 Total Number of RTGS

The number of RTGS transactions increased from 1,592 lakh in 2020–21 to 2,426 lakh in 2022–23. This represents a cumulative growth of over 52% in just two years. The growth suggests that more businesses, institutions, and banks are using RTGS to transfer large amounts in real-time, likely due to its speed, reliability, and real-time confirmation.

The total value of RTGS transactions rose from ₹105.6 lakh crore in 2020–21 to ₹149.9 lakh crore in 2022–23. That's an increase of approximately 42% over two years. This rise reflects a stronger macroeconomic environment, with higher business volumes, increased investment activity, and the government's initiative for digital India.

UPI:

Unified Payments Interface (UPI) is a real-time payment system introduced in 2016 by the National Payments Corporation of India (NPCI), under the supervision of the Reserve Bank of India (RBI) and the Indian Banks' Association (IBA). It allows users to instantly transfer funds between bank accounts using a mobile phone via any UPI-enabled application.

TABLE VI:
GROWTH OF UPI IN INDIA

YEAR	Transaction (in crore)	Value (₹ Lakh Crore)
2016–17	1.0	0.69
2017–18	91.5	1.09
2018–19	535.5	8.77
2022–23	8,375	139.00
2023–24	11,660+	180.00+

Source; Reserve bank of India

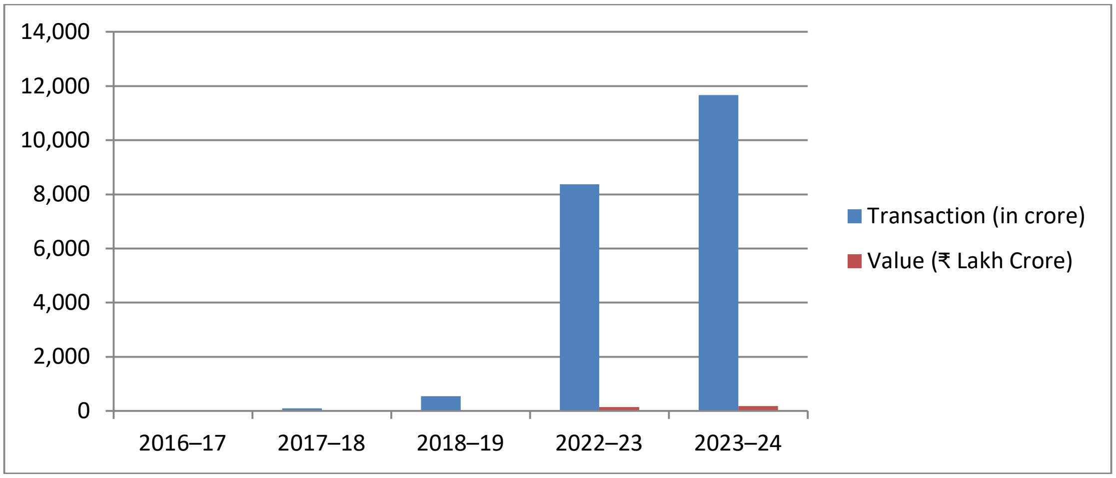


Fig. 5 Total Number of UPI Transaction

The Unified Payments Interface (UPI) has revolutionized India's digital payments ecosystem by offering a fast, secure, and real-time platform for conducting financial transactions. Introduced in 2016 by the National Payments Corporation of India (NPCI), UPI has experienced exponential growth in recent years. Transaction volumes surged from 1,252 crore in FY 2019–20 to over 11,660 crore in FY 2023–24, while the total transaction value skyrocketed from ₹21.31 lakh crore to more than ₹180 lakh crore. This phenomenal growth highlights UPI's broad acceptance across various segments of the population, including urban professionals, online shoppers, small business owners, and rural users.

The success of UPI can be attributed to several factors, including its simplicity, cost-effectiveness (most transactions are free), and government initiatives promoting cashless payments under the Digital India program. The ease of transferring money using just a mobile number or UPI ID, without the need for account details or IFSC codes, has significantly enhanced user convenience. Additionally, UPI's interoperability across multiple banks and apps such as Google Pay, PhonePe, Paytm, and BHIM has made it a go-to payment method for everyday use. The system also supports merchant payments, bill payments, subscription mandates, and QR-based transactions, expanding its utility far beyond person-to-person transfers.

UPI has not only outpaced traditional payment methods like debit cards, credit cards, NEFT, and IMPS in terms of transaction volume but has also promoted financial inclusion by empowering millions of unbanked and underbanked citizens to participate in the digital economy. Its expansion to international markets further indicates its growing recognition as a model for modern payment systems. As India moves towards a less-cash economy, UPI continues to be the cornerstone of digital transformation in the financial sector, driving transparency, efficiency, and innovation in transactions.

NEFT

The National Electronic Funds Transfer (NEFT) system enables individuals to transfer money from one bank account to another across India, regardless of location. It functions through a network of participating banks and operates in scheduled batches throughout the day on weekdays and working Saturdays. Managed by the Reserve Bank of India (RBI), NEFT provides a reliable and efficient way to carry out interbank transfers during designated time slots.

In 2019, NEFT recorded around 262 crore transactions amounting to ₹232.97 lakh crore, and by 2024, the volume jumped to nearly 927 crore transactions, with a value exceeding ₹432 lakh crore. This growth indicates a consistent increase in digital adoption, especially among businesses and institutions that require scheduled or large-value transactions. NEFT's transition to a 24x7x365 service since December 2019 also played a crucial role in boosting its usage, as it eliminated the time constraints associated with traditional banking hours.

NEFT continues to be favored for its structured settlement batches, security, and suitability for mid to high-value transactions that are not time-sensitive. Compared to real-time systems like UPI or RTGS, NEFT offers a balance of convenience and formality, making it ideal for salary disbursements, vendor payments, utility bills, and personal fund transfers. Furthermore, its integration with internet and mobile banking platforms has made it more accessible to users from all age groups and regions.

In summary, while UPI dominates small-value retail payments, NEFT remains a pillar of India's digital payment infrastructure for formal, scheduled, and high-value transactions. Its continued growth underlines the ongoing digital shift in the country's financial habits, especially in the organized sector and enterprise landscape.

NEFT usage has been increasing steadily, with Average annual growth rate of 26% over the past 4 years! Even though there aren't many transactions, they involve a lot of money. On average, the size of these transactions has Difference between Rs 60 Thousand and 1 Lakh over the Last 5 years.

PAPER MONEY (CHEQUE)

India has one of the best clearing house infrastructures, enabling markets and businesses across the country to clear payments and settle them within two days. It is a preferred mode of transaction.
Cheques, once the backbone of formal financial transactions in India, have witnessed a significant decline in usage over the past decade due to the rise of digital payment methods. As a traditional instrument of payment, cheques were widely used for everything—from salary disbursements and business payments to personal transactions and bill settlements. However, with the rapid adoption of real-time digital channels such as NEFT, RTGS, and especially UPI, the use of paper-based payments like cheques has reduced considerably. Despite this decline, cheques still hold a place in the Indian financial system, particularly among older generations, rural users, and formal business setups that prefer or require written records and documentation. Cheques are often considered safer for high-value or scheduled payments, and are still mandated in certain government and institutional transactions, such as EMI payments, insurance premiums, or security deposits.

The Reserve Bank of India and commercial banks have also modernized cheque handling through Cheque Truncation System (CTS), which allows for faster and more secure clearance by digitizing the physical cheque. However, in comparison to digital alternatives, cheques are slower, require manual handling, and have a higher chance of rejection or fraud. Statistical trends show that both the volume and value of cheque transactions have steadily declined year-on-year, as individuals and businesses increasingly favor electronic payment methods for their speed, convenience, and 24x7 availability. This trend reflects a broader shift in India's economic behavior—from paper-based to digital banking—fueled by mobile penetration, financial inclusion initiatives, and trust in secure payment gateways. In conclusion, while cheques are still in use, especially for formal and legacy transactions, their relevance in India's modern payment landscape is diminishing. The shift toward cashless and paperless transactions is evident, and cheque usage is likely to continue its downward trajectory in the years ahead.

Analysis of Different Payment systems

There are several types of payment systems available today, each with its own strengths and weaknesses. **Cash payments** are the most traditional method, offering instant settlement without any transaction fees. They are simple and universally accepted in physical settings. However, cash is not suitable for online transactions and carries a higher risk of loss or theft, making it less ideal in the digital age.

TABLE VII:

Payment System	Transaction Volume	Transaction Value	Share in Digital Payments Volume	Year-on-Year Growth
UPI (Unified Payments	131 billion transactions	₹199.89 lakh crore	80%	Tenfold increase over four years

Interface)				
NEFT (National Electronic Funds Transfer)	Data not specified	₹1,199.43 lakh crore	49.4% of total retail payments value	Data not specified
IMPS (Immediate Payment Service)	5.999 billion transactions	₹64.93 lakh crore	Data not specified	9% increase in volume

Source: Reserve Bank of India

The Reserve Bank of India (RBI) collects and shares data about transactions made through payment systems, showing how many transactions happen and how much money is involved. They also calculate a helpful metric called Average Transaction Size (ATS) to help us understand these systems better. The chart below displays the percentage of different Payment systems based on number of transaction they handled.

The charts clearly show that RTGS, NEFT, and paper (cheques) dominate in terms of transaction value, while other payment modes lead in volume, indicating they are used for smaller transactions.

VI. CONCLUSION

Virtual banking—also referred to as electronic banking or e-banking—has become an integral component of the contemporary financial ecosystem. Driven by rapid technological advancements, banks are now equipped to deliver a comprehensive suite of services through digital platforms, offering customers greater convenience, accessibility, and efficiency than ever before. This digital shift has transformed the traditional banking experience, enabling individuals to carry out virtually all financial transactions without visiting a physical branch. From opening new accounts and checking balances to transferring funds, applying for loans, and paying utility bills, customers can now manage their finances entirely through online portals or mobile banking applications. These platforms are designed to be user-friendly, secure, and available 24/7, significantly enhancing the overall customer experience. One of the most notable impacts of virtual banking has been the reduction in dependence on physical cash. As digital transactions become the norm, banks have been able to streamline operations, reduce overhead costs, and improve operational efficiency. This has also contributed to broader financial inclusion, allowing people in remote or underserved areas to access essential banking services. The growth of virtual banking has been further fuelled by the widespread issuance of debit and credit cards and the rapid expansion of digital payment infrastructure. Systems such as the Unified Payments Interface (UPI), Immediate Payment Service (IMPS), and National Electronic Funds Transfer (NEFT) have played a key role in facilitating secure, real-time electronic transfers. As a result, there has been a sharp increasing the volume and value of electronic transactions across the country.

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MyHealthily: An AI-Powered Conversational Assistant for Personalized Healthcare Guidance A Research Implementation Using Natural Language Processing

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Abstract: This study introduces My Health Ally, a conversational assistant driven through the use of natural language processing (NLP) in artificial intelligence (AI) to deliver tailored healthcare advice. The vision of this article is to create and deploy a user-centered virtual assistant that can comprehend, process, and reply to natural language inquiries about health. By using cutting-edge NLP techniques, My Health Ally seeks to close the gap between patients and medical professionals by providing trustworthy information, symptom checking, and wellness advice based on each user's unique needs. To improve user engagement and trust, the system design incorporates contextual language understanding, medical databases, and machine learning models.

Keywords: Artificial Intelligence, Natural Language Processing, Conversational Assistant, Chabot.

I. INTRODUCTION

As the demand for accessible and efficient healthcare services continues to grow, innovative digital solutions are becoming increasingly essential. Among these, AI-powered chatbots have gained prominence in the healthcare sector by facilitating tasks such as symptom checking, medication suggestions, and appointment management. These intelligent systems enhance patient engagement by offering timely, relevant information, guiding users toward appropriate healthcare resources, and alleviating the workload on medical professionals. This research focuses on the development of a conversational healthcare assistant—My Health Ally—that supports university students in managing health-related concerns and accessing on-campus medical resources, ultimately contributing to more streamlined and effective healthcare service delivery.

MyHealthAlly features a variety of services, including symptom analysis, medication suggestions, appointment scheduling, and lifestyle guidance. It facilitates interactive conversations, enabling students to take a proactive approach to their well-being, while also providing health analytics to monitor symptoms, ensure medication adherence, and track health trends. By alleviating the burden on healthcare staff and expanding access to underserved areas, MyHealthAlly showcases the transformative power of AI in reshaping healthcare systems. Myhealthally has been developed as an innovative solution. This ai-driven healthcare chabot is designed specifically for university settings, recognizing the unique needs and challenges faced by students. The platform integrates several advanced technologies, artificial intelligence, and natural language processing to provide a seamless and efficient healthcare experience.

With the help of AI and machine learning, MyHealthAlly can analyze reported symptoms and provide students with an informed understanding of what might be happening with their health. It can also suggest over-the-counter medications or

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lifestyle changes based on symptom severity and other contextual factors. While it does not replace professional medical advice, it serves as a preliminary step for individuals to get a better idea of what may be causing their symptoms.

Artificial Intelligence, particularly manifested through chatbots, has emerged as a transformative force in various sectors, including healthcare. These chatbots simulate human-like conversational interactions and are increasingly utilized to enhance patient engagement and provide preliminary healthcare assistance. The innovative approach of employing chatbots in health informatics aims to bridge the gap between patients and healthcare providers, especially in post-consultation scenarios where patient engagement tends to decline. By leveraging natural language processing capabilities, these chatbots facilitate symptom analysis and disease diagnosis through intuitive conversations with users, thereby offering personalized recommendations and even suggesting suitable specialists if needed [1]

Chatbots are artificial intelligence (AI) systems that replicate human interactions through natural language processing mechanisms. Although this generation is still in its infancy, fitness chatbots could potentially increase access to healthcare, improve verbal communication between patients and doctors, or help manage the increasing demand for fitness services like remote testing, adherence monitoring, or teleconsultations. The creation of chatbots enables activities like accurate fitness assessments, setting up private fitness-related reminders, communicating verbally with medical teams, scheduling appointments, retrieving and evaluating fitness data, and interpreting diagnostic styles based on behavioral indicators like sleep, nutrition, or body activity. Nine These generations might wish to change how healthcare frameworks are shipped, which would increase acceptance [2].

II. LITERATURE REVIEW

The integration of artificial intelligence into healthcare, particularly through chatbot systems, has garnered increasing academic and practical interest over the past decade. Several Research has shown that the utility of AI-driven conversational agents in enhancing healthcare accessibility, supporting preliminary diagnostics, and improving patient engagement. Lin Ni et al. (2017) introduced “MANDY,” a smart primary care chatbot aimed at enhancing healthcare accessibility, especially in resource-limited settings. Their work underscores the potential of AI in reducing the burden on healthcare professionals while offering patients basic medical advice. Divya et al. (2018) suggested a medical chatbot that can diagnose itself that leverages artificial intelligence to interpret user inputs and provide relevant diagnostic outputs, thereby emphasizing automation in symptom checking and initial assessment. Further advancing the application of AI, Kavitha and Murthy (2019) developed a healthcare chatbot system that focused on improving communication between patients and medical professionals. Meanwhile, Hiba Hussain et al. (2020) integrated NLP,ML, and OCR in their disease prediction chatbot, marking a significant technological step toward robust and multifaceted chatbot systems. These pioneering efforts lay the groundwork for modern healthcare chatbot systems like Ada Health and Woebot, which have further expanded the scope to include mental health support and comprehensive symptom tracking. The evolution of AI healthcare chatbots is also evident in the adoption of transformer-based NLP models such as BERT and GPT, enabling more nuanced and human-like interactions between patients and virtual agents [1].

This progression in literature reflects the trajectory from rule-based systems to intelligent, learning-based platforms capable of contextual understanding and dynamic response generation, thereby highlighting the transformative potential of AI chatbots in modern medical practices [1].

The study of fungal evolution through geological time has been challenging due to the delicate, non-mineralized nature of fungal tissues. However, fossil records across the Precambrian and Paleozoic eras provide crucial insights into the antiquity and adaptive strategies of fungi, particularly when analyzed in the context of Indian stratigraphy. In the Precambrian era, fungal-like microstructures have been reported from chert deposits and stromatolitic environments, suggesting a possible presence of primitive fungal forms. Although these findings remain debated due to poor preservation, they open discussions on the pre-vascular plant colonization of land by fungal organisms. Moving into the Paleozoic era, especially from the Silurian to the Devonian, more definitive fungal fossils emerge. These include hyphae, spores, and evidence of early symbiotic relationships such as lichenization and mycorrhizal associations. Such findings mark the beginning of fungi’s ecological integration with terrestrial ecosystems. The Carboniferous and Permian periods represent a turning point, particularly within the Indian Gondwana formations. Studies of coal-bearing sequences such as the Barakar and Raniganj formations have revealed abundant fungal remains. These fossils—ranging from reproductive structures to hyphal networks—highlight fungi’s role as decomposers and symbionts, crucial to nutrient cycling in early forest ecosystems [3].

These findings not only reinforce the evolutionary resilience of fungi but also position India's fossil record as a critical contributor to global pale mycological knowledge. The literature collectively suggests that fungi have evolved from simple, isolated structures to highly integrated ecological partners, paralleling the rise of terrestrial flora [3].

Artificial Intelligence (AI) has rapidly evolved to support decision-making across various domains, particularly in healthcare and behavioral sciences. Numerous studies have demonstrated that AI-driven systems can predict disease outbreaks, improve diagnostic accuracy, and personalize treatment plans. Machine Learning (ML) models, like Deep Neural Networks (DNN), Random Forests (RF), and Support Vector Machines (SVM), have been extensively applied to medical datasets for early disease detection, such as heart disease, cancer, and diabetes. Behavioral analysis using AI leverages data from wearable devices, online behavior, and social media activity to assess mental health, predict emotional states, and track lifestyle patterns. Studies have shown that sentiment analysis and natural language processing (NLP) techniques can accurately infer psychological conditions from textual data, aiding early interventions. The convergence of AI with human behavior analytics offers transformative potential in areas like smart healthcare monitoring, personalized mental health support, and preventive care. However, challenges remain, particularly in data privacy, algorithmic bias, and the need for transparent, explainable AI models to ensure ethical implementation [3].

The study of noise pollution and its impact on urban environments has gained increasing attention over the past few decades. According to Bhagat et al. (2021), urban noise is a significant contributor to environmental stress and can adversely affect human health, particularly in densely populated areas. Similarly, Singh and Davar (2004) highlighted that Prolonged exposure to high noise levels leads to both physiological and psychological health issues, including hearing loss, stress, and reduced productivity. In India, the Central Pollution Control Board (CPCB) has established noise standards to mitigate these effects, but enforcement remains inconsistent (CPCB, 2011). Gupta and Goyal (2017) studied noise levels across multiple Indian cities and found that most urban centers exceed permissible noise limits, especially during peak traffic hours. Kumar et al. (2018) conducted a comparative study of noise levels in residential, commercial, and industrial areas, finding commercial zones consistently had the highest noise exposure. Additionally, WHO (2018) emphasized the global burden of disease attributed to environmental noise, estimating that nearly one million healthy life years are lost annually in Western Europe alone due to traffic-related noise. This underlines the need for more robust urban noise management strategies worldwide [4].

The current study builds upon these findings by focusing specifically on traffic noise pollution in Nagpur, Maharashtra, across five critical locations, thereby contributing region-specific data to the broader discourse on urban noise pollution in India [4]. The association between wind turbine noise (WTN) and human health has been extensively studied over the past two decades. Numerous investigations have revealed that exposure to WTN can cause annoyance, sleep disturbances, and potential psychological effects in nearby residents [4]

III. PROPOSE METHODOLOGY

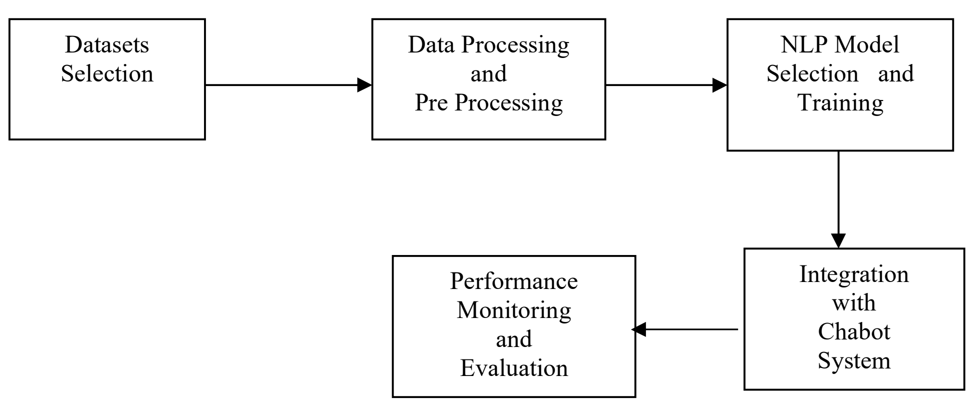

Fig 1. Propose Methodology

***A. NLP Dataset Selection*:**

The performance and accuracy of the chatbot are highly influenced by the quality of the datasets used for its training. For the best results, it is important to utilize diverse and comprehensive healthcare-related text data. This includes a variety of content such as patient inquiries, medical consultations, and clinical documentation, which help the model grasp the nuances of healthcare communication. Suitable datasets can be sourced from medical forums, open-access medical text repositories, and health-focused conversational data collections.

B. Data Processing and Preprocessing:

To enhance the model's performance, the raw data must go through several preprocessing steps. Text normalization involves standardizing the text by converting it to lowercase, removing punctuation, and handling special characters to ensure consistency. Tokenization breaks the text into smaller units like words or phrases, making analysis simpler. Stop word removal filters out frequently used words such as "and" or "the" that add little value to the meaning of the content. Finally, stemming and lemmatization reduce words to their base or root form (e.g., "running" to "run"), which helps in treating different word forms as a single term, thereby improving consistency and model understanding.

C. NLP Model Selection and Training:

Choosing the right NLP model is crucial for building an effective healthcare chatbot. Pretrained models like BERT and GPT are ideal due to their advanced language processing capabilities, allowing developers to save time while benefiting from strong language understanding. For more specialized performance, custom models can be fine-tuned to handle domain-specific tasks such as intent classification and entity recognition in healthcare contexts.

There are various important steps in the training process. First, the dataset is divided into training, validation, and test sets to ensure balanced performance. During model training, the system is taught using the training set with a focus on healthcare-related tasks. The validation set helps fine-tune model parameters and avoid over fitting, while the evaluation phase uses the test set to assess the model’s effectiveness through metrics like accuracy, precision, recall, and F1 score.

D. Integration with Chabot System:

Integrating NLP models into the chatbot system involves several core components. Intent recognition helps the chatbot understand user goals, such as asking about symptoms or scheduling appointments. Entity recognition extracts important information like symptoms, diagnoses, medications, and doctor names, enabling accurate and relevant responses. Dialogue management uses algorithms to control the flow of conversation, ensuring the chatbot stays coherent and contextually appropriate based on the identified intents and entities.

E. Performance Monitoring and Evaluation:

To ensure the Chabot operates effectively, real-time monitoring tools are essential for tracking key performance indicators such as response time, accuracy, and user engagement. Additionally, performance metrics like response relevance, task completion rate, and overall user interaction provide valuable insights. These metrics are critical for continuous improvement, helping maintain the Chabot’s efficiency, accuracy, and user-friendliness over time.

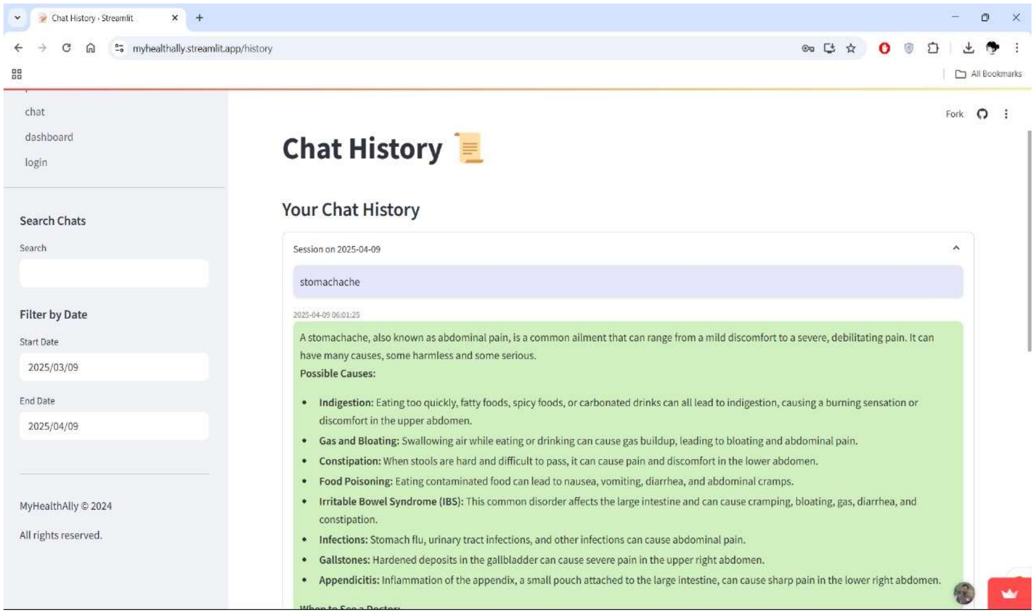

Fig. 2: Chat history interface

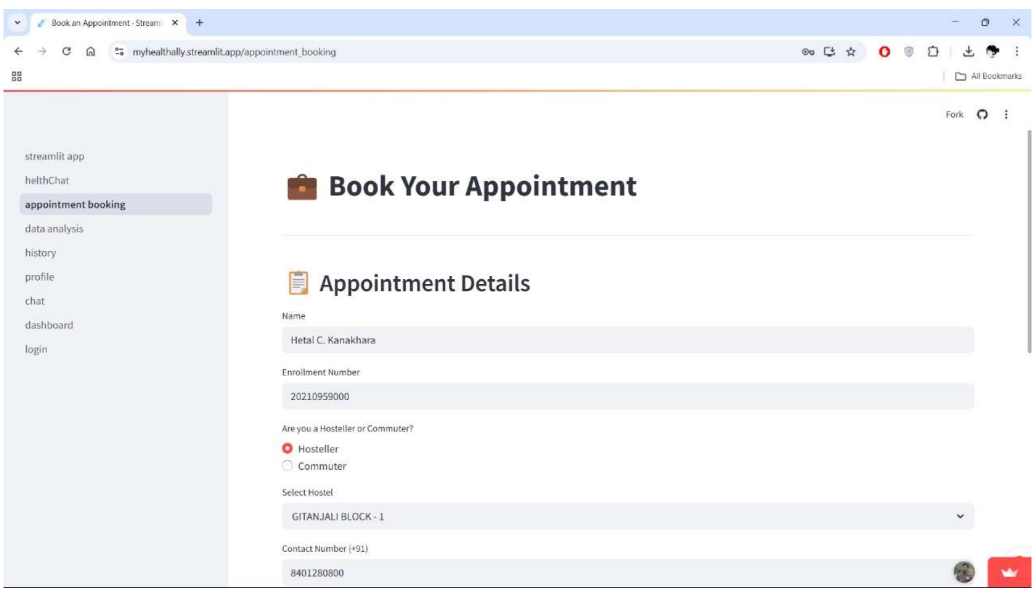

Fig. 3: Appointment interface

IV. RESULT

TABLE I:
RESULT COMPARATION

Test Case ID	Test Scenario	Input	Expected Output	Actual Output	Status
TC- 001	Chatbot UI responsiveness	Open the chatbot on various devices (mobile, tablet, desktop)	Chatbot UI adapts to the screen size, with all buttons and text clearly visible	Chatbot UI adapts to all devices as expected	Passed
TC- 002	Symptom input validation	Enter valid symptoms (e.g., fever, cough)	Chatbot suggests possible conditions, recommended medicines, and consultation details	Chatbot provides accurate suggestions and details	Passed
TC- 003	Symptom input validation	Enter invalid/unrecognizable input(e.g., random characters)	Chatbot responds with a message like "I'm sorry, I don't understand. Please provide valid symptoms."	Chatbot displays the correct error message	Passed
TC- 004	Symptom analysis	Input multiple symptoms (e.g., headache, nausea)	Chatbot provides possible conditions with probabilities and advice	Chatbot provides accurate analysis	Passed
TC- 005	Medicine availability check	Enter symptoms with available medicine on campus	Chatbot displays the medicine name, location ,and faculty to contact	Chatbot displays correct medicine and details	Passed
TC- 006	Medicine unavailability	Enter symptoms for which no medicine is available	Chatbot suggests alternative actions(e.g., consult a specialist)	Chatbot displays accurate alternative actions	Passed
TC- 007	Faculty consultation	Ask for faculty details for medicine distribution	Chatbot provides faculty name ,contact details, and availability	Chatbot displays accurate faculty details	Passed
TC- 008	First- aid room navigation	Ask for first-aid room location	Chatbot provides clear directions or a campus map	Chatbot displays accurate directions	Passed
TC- 009	CSV data integration	Enter a symptom available in the CSV dataset	Chatbot retrieves accurate and relevant details based on the CSV file	Chatbot retrieves data accurately	Passed
TC- 010	Security and privacy	Enter personal information (name, age, symptoms)	Chatbot ensures data confidentiality and provides an appropriate privacy statement	Chatbot maintains confidentiality and displays privacy statement	Passed
TC- 011	Error handling	Enter unsupported commands (e.g., "Tell me a joke")	Chatbot gracefully handles errors with a friendly response like "I'm here to assist with	Chatbot displays appropriate error message	Passed

V. CONCLUSION

The creation of My Health Ally, an AI-powered healthcare chatbot, marks a critical turning point in the discussion of healthcare efficiency and accessibility in academic contexts. With the use of artificial intelligence and natural language processing, the chatbot can accurately analyze symptoms, recommend medications, and schedule visits with medical professionals. My Health Ally gives students the tools they need to take charge of their health with features like medication adherence tracking, personalized lifestyle suggestions, and health analytics. Confidentiality and usability have been guaranteed by the project's successful implementation of user-friendly interfaces and safe data handling. This project demonstrates the revolutionary potential of AI in healthcare systems by improving healthcare accessibility while also lessening the effort for medical personnel

VI. FUTURE WORK

The project lays a solid foundation for future advancements, offering numerous opportunities to enhance functionality, scalability, and overall user experience. One key area of improvement is enhanced symptom analysis and diagnosis, where future iterations can integrate advanced machine learning models for more accurate symptom mapping and differential diagnosis. Expanding the symptom database will also allow the chatbot to address more complex health issues. Integration with external medical systems is another crucial development, enabling seamless data sharing through connections with electronic health records (EHRs) and university health center databases, which will support better continuity of care and informed decision-making.

Improving mobile and cross-platform availability is also essential. Developing dedicated mobile apps with features like push notifications for medication reminders and appointment alerts can significantly boost user engagement. Lastly, the platform can be expanded beyond university settings to serve larger communities, including workplaces and rural areas, thereby helping to bridge healthcare access gaps for underserved populations.

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Assessment of Institutional Library R.C.C Building in Ahmedabad

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Abstract: Population is rapidly growing in the developing country like India. Urbanization and demand of land is increasing. Increase in construction and material cost leads investor in trouble. About 30% of Construction industry creates pollution and dumping of construction waste materials are also a serious issue. Repair and Rehabilitation of structures is the only solution to conserve the structure. Buildings are designed according to standard codes but periodic monitoring & investigation are required for structure good health during service life. In the present case study, Reinforced concrete G+2 (including basement) an institutional R.C.C building is investigated. The distress in the building is seen in structural and non-structural elements. The major cause of distress was due to leakage of drainage and sewage pipelines.

Keywords: repair, retrofit, rehabilitation, residential building, structural failure, rejuvenation

I. INTRODUCTION

Concrete is a versatile material [1] It can be molded into any shape as per requirement [1] Concrete is the second most material widely used after water. The properties of fresh concrete and hardened concrete may differ due to aging of material. The regular inspection is required to maintain the functioning of building according to its use. The distress in the structure may be due to physical, chemical or environmental agencies. The defeats in the structure are crack, spalling, corrosion, peeling, dampness etc. In such situation evaluation of damages in structure is necessary and proper treatment should be adopted with good practices.

In Ahmedabad a premier institution LD College of Engineering library building was assessed in the year 2019. The distress observed in the building is classified into structural and non-structural elements. In structural element different types of cracks, spalling and corrosion and non-structural element distress like crack, dampness, staining and peeling of paints were observed. Some of the major reasons for distress in the structure are ageing, environmental effect, inadequate maintenance, change in load pattern and leakage of water and sewage lines.

II. OBJECTIVE OF THE STUDY

The primary objective of this study is to investigate and analyze the causes and extent of distress observed in a reinforced concrete (R.C.C) G+2 institutional building, including its basement. The study specifically aims to:

1. Identify the nature and extent of structural and non-structural distress in the building elements.
2. Examine the impact of leakage from drainage and sewage pipelines on the integrity of the structure.
3. Determine the root cause(s) of deterioration and damage to the concrete and reinforcement.
4. Assess the current condition and safety of the structure for continued usage.
5. Recommend appropriate remedial measures and strategies for repairing, strengthening, and preventing future damage.
6. Provide insights for improving construction practices and maintenance to avoid similar issues in future projects.

http://doi.org/10.63766/spujstmr.24.000039

III. LITERATURE REVIEW

Surresh Chandra Pattanaik et al (2011) Paper presented on institutional building located in south India. The G+1 and G+2 buildings experienced severe damage due to water leakage and environmental factors. The structure was safe under NDT test and minor repair and rehabilitation was done. The masonry walls of laterite stone was disintegrated, spalling of plaster, fungal growth and corrosion of reinforcement are observed. The steel jacketing was done on structural members for strengthening of building.

Varinder K. Singh (2012) Paper presented case study on repair and rehabilitation of G+8 multi-storeyed ONGC residential colony, Ahmedabad Gujarat. The building was severely affected after the Bhuj earthquake 2001. The distress seen in the buildings are cracks, spalls and corrosion of steel reinforcement. Several test were carried out like UPVT, Carbonation Test and Chloride Test. The structural member for 5 columns and 6 beams strength should be 20 N/mm2 but shows poor result estimated strength was 10 N/mm2 using UPV test. The corrosion in the structural elements was serve and deeply affected about 78mm in column and 35mm in beam using carbonation test. In the chlorine test, the permissible value of acid soluble chloride should be 0.25 gm/kg but during investigation it was found to be greater than 1.00 gm/kg. The severely affected columns and beams are jacked with PMM and cracks are repaired with epoxy grouting.

Prof. Y. R. Suryavanshi et al (2014) Paper discussed about RCC Frame building investigated for structural and non-structural members. The NDT tests were carried out such as Rebound hammer test, carbonation test, pH value, and UPV Test and found that structure need minor repair. The author had concluded that demolition of existing building cost more than repair and rehabilitation of building. And life of structure increase by 15 to 18 year by repair techniques.

Balamurali krishnan R et al (2016) Paper discussed about selection of repair materials and different repair techniques using a Beam. The selected materials for beam repair work are Polymer modified concrete, Glass Fiber Reinforced Polymer and Carbon Fiber Reinforced Polymer. Based on the results, CFRP increased the flexural strength by 18–20% with a single layer and by 40–45% with a double layer.

Yasir Shaikh et al (2019) Present paper studied an assessment and repair of institutional G+1 RCC building Dabhi, Gujarat. The building is showing signs of distress due to dampness, shrinkage, and environmental effects. The different types of cracks in non-structural elements are observed. The test results of NDT were carried out and found good and satisfies the criteria. The rebound hammer test shows average 35 N/mm2 strength of concrete shows good results. Carbonation, sulphate and chloride results show no corrosion in reinforcement bar. Paper concludes with providing treatment of cracks, dampness and termite.

IV. BACKGROUND STUDY

Institutional building of LDCE Ahmedabad was constructed in 1948; the design life period of building is 100 years. The buildup area of Library Building was 2845.85 sq. meter. A Reinforced concrete G+2 (including basement) is functional for library and reading room.

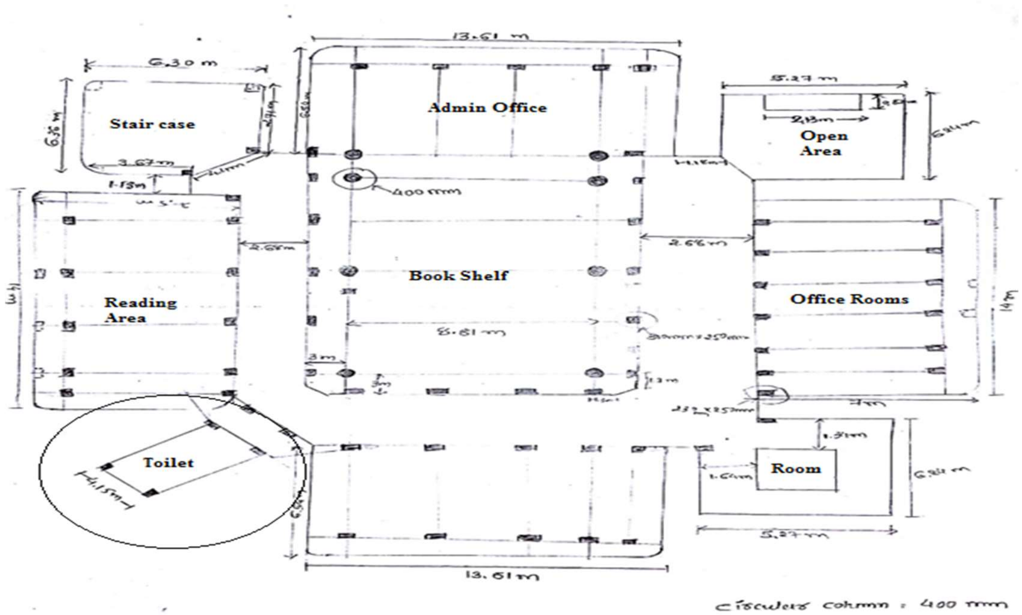

Fig.1. Plan of Library Building

The Plan of library building is shown in fig. 1. The major distress was observed in the toilet block area on the first floor (as shown in the highlighted circular area) and in the space directly below it on the ground floor, which was allotted as a store room. The highlighted zone had remained unused for several months.

V. CODAL PROVISION FOR REPAIR & REHABILIATION OF BUILDINGS

A. Handbook on repair and rehabilitation of RCC Buildings

The main objective of condition survey is to identify the causes and sources of distress and select the plan for effective remedial measures [6] The flow chart of condition survey decides that Testing stage is required or not is shown in figure: 2[

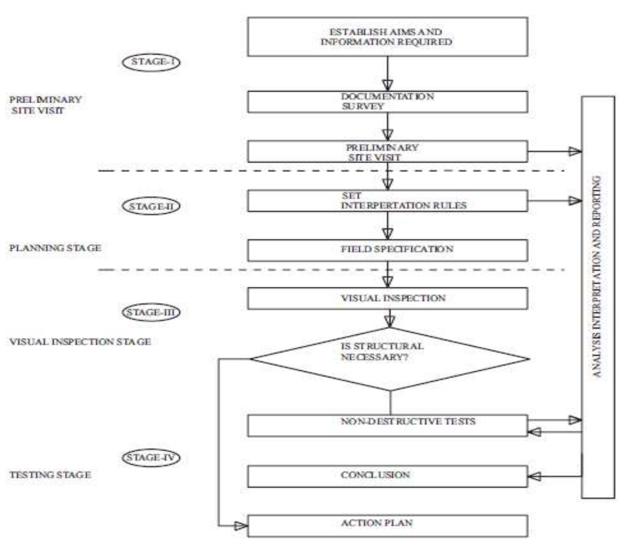

Fig.2. Flow chart showing condition survey [6]

This above flowchart outlines a systematic approach for investigating structural distress in a building, divided into four stages**:**

Stage I: Preliminary Site Visit

- Establish Aims and Information Required: Define the purpose and scope of the investigation.
- Documentation Survey: Review drawings, previous reports, and records.
- Preliminary Site Visit: Conduct an initial visual check to understand the condition.

Stage II: Planning Stage

- Set Interpretation Rules: Define criteria for assessing damage and deciding further action.
- Field Specification: Plan resources, team, equipment, and testing locations.

Stage III: Visual Inspection Stage

- Visual Inspection: Detailed inspection of the site to identify distress signs.
- Decision Point: Assess whether structural testing is necessary based on visual findings.

Stage IV: Testing Stage

- Non-Destructive Tests (NDTs): If needed, conduct tests like rebound hammer, ultrasonic pulse velocity, etc.
- Conclusion: Analyze all findings to determine the causes and severity of distress.
- Action Plan: Propose remedial measures, repair strategies, and preventive recommendations.

TABLE I:
TESTS TO DETERMINE THE QUALITY OF CONCRETE

Sr. No	Test Name	Test Value
1.	Rebound Hammer Test	>40 Very good Quality
2.	Ultra-Pulse Velocity Test	>4.0 km/s Very good Quality
3.	pH Value	>11.5 No corrosion
4.	Half-cell potential	<5% probability of corrosion is less

A. IS 456 2000 Code of Practice Plain and Reinforced Concrete

The stakeholder uses this code for concrete structure. The code talks about limit state method using safety serviceability, workability, durability and aspects. The special design requirements for structural elements such as beams, columns, and slabs are defined.

B. IS 15988: 2013 Seismic Evaluation & Strengthening of Existing Reinforced Concrete Buildings

The code discuss about the preliminary investigation and detailed investigation of concrete members. Strengthen of structural members using column jacking; fiber jacking beam, steel bracing at joints and reducing of structural irregularity are also covered.

C. IS 13935: 2009 Seismic Evaluation, Repair & Strengthening of Masonry Buildings

Selection of repair materials for strengthening of masonry damaged due to earthquake like shotcrete, epoxy resin, quick setting cement mortar, mechanical anchors, fiber reinforced plastics are covered. The suitable techniques for repairs are repair of minor to major cracks, horizontal seismic belts; vertical seismic belts at corners, strengthening with wire mesh are studied.

VI. PRELIMINARY INVESTIGATION

Visual inspection for Library building was carried out. If a building has given about 25 to 30 years of service without much maintenance or repair then it is reasonable to expect that it would need some repair sooner or later. The different types of crack observed in the structure are bonding cracks, shrinkage cracks, diagonal cracks and longitudinal cracks. The measured crack wide was >2mm.

Fig.3 Different Cracks (a) bonding crack (b) longitudinal crack (c) shrinkage crack (d) diagonal crack

The improper bonding between structural and non-structural element leads to bonding cracks in figure: 3 (a). The longitudinal cracks may be observed in structural element due to insufficient cover of the member in figure: 3 (b). The improper curing and weathering effect the shrinkage cracks develops in figure: 3 (c). Due to varying temperature shrinkage crack occurs which increase in crack leads to diagonal crack in masonry walls figure: 3 (d). Due to ageing the crack in the structure lead to widen up and enlarge if not proper repair treatment are done. The external agencies like physical, chemical or environmental aspects would enter into the cracks and make the distress worse. It also leads to other distress like spalling, staining, corrosion etc.

The spalling is observed in slab, reinforcement are observed. Over time, corrosion of the reinforcement begins. The major causes of spalling are insufficient cover, cracks, shrinkage, weathering effects in figure: 4.

Fig.4 Spalling & Corrosion of reinforcement in structural element

The staining effects are observed in the structure due to leakage of pipelines. The improper sealants in joints leakage of water leads to growth of plants in figure: 5

Fig.5 Staining effects

Due to leakage of water and drainage pipelines dampness and peeling of paints in the structure are also observed in figure:6

Fig. 6 Peeling of paints and dampness effects

VII. REPAIR STRATEGY

The following strategies for the rehabilitation of concrete and masonry structure are:

1. Cleaning of damaged concrete and plasters.
2. Cleaning of corroded steel reinforcement in slab by manual or mechanical means and applies corrosion inhibitor [FAIRCRETE C].
3. Jacketing of slab can be done to steel reinforcement in slab for strengthening.
4. Application of Polymer Modified Mortar (Synthetic Butadiene Polymer Latex with 43 Grade OPC cement) in 15-20 mm thick layers in each old concrete/plaster with new layers.
5. Epoxy grouting in masonry and structural members like slab and beams to repair cracks.
6. Polymer Modified Mortar in masonry and structural members to crack sealants.
7. Replacement of leakage water lines drainage and sewage pipelines.
8. Sealants of joints pipelines.
9. Re-plastering and Painting with Acrylic paints.

VIII. REPAIR MATERIALS

The selection of material is chosen based on hand book on repair and rehabilitation published by Director General Works CPWD, Government of India [6]

Grout Material

The injection of epoxy grout material (low viscosity) into structural and non-structural member by using pneumatic grouting technique for restoration of the structural integrity of cracked concrete. The Pidilite Dr. Fixit epoxy material cost approx. 575 per liters.

Polymer Modified Mortar (PMM)
Styrene-butadiene latex-modified mortars and concrete are suitable for a multiple applications. Due to the properties like bond to substrate and low permeability are most important. SBR Latex @ 20% by weight of OPC in PMM. The mix proportion 1:3 with water/binder ratio of 0.35 (1 - 43 Grade OPC meeting specification of IS 8112 Cement: 3 - Coarse Sand meeting the requirements of Zone II sand of IS 383) used in RCC repair. The Styrene-butadiene latex Polymer material cost approx. 120 per liters.

Asian Paints Smart Care Damp Block
Asian Paints Smart Care Damp Block is a polymer modified, flexible cementations waterproof coating. It is a high performance cementations material formulated with elastic waterproofing polymers, nano technology based additives and crystalline technology. The Asian Paints Smart Care Damp Block material cost approx. 190 per liters.

Asian Paints Smart Care Vitalia
Asian Paints Smart Care Vitalia is an integral liquid waterproofing compound with advanced formulation and superior plasticizing additives for cement concrete, mortar and plasters. The product is formulated with selected surface active plasticizing agents, chemicals & additives which make the cement concrete/plaster mix cohesive and upon curing, reduces water permeability. The Asian Paints Smart Care Vitalia material cost approx. 235 per liters.

IX. REPAIR METHODOLOGY

Repair Methodology is an important feature for any project. The correct adoption of technique results in good practice. The following sequences are to be followed for any structural repair and rehabilitation projects:

1. Identify the location and documents of Project
2. Study Environmental Aspects
3. Visual inspection of distress
4. **Preliminary investigation**
   - Finding the location of distress
   - Identifying the cause of distress
5. Detail investigation (if required)
   Using methods like NDT SDT and DT
   - NDT - Rebound Hammer test, Ultrasonic Pulse Velocity test, Carbonation Test, Radiography test etc.
   - SDT - Penetration test, Pull off – Pull out Test, Core Test etc.
   - DT - Tensile strength test, Compressive strength test, hardness test etc.
6. Possible diagnosis techniques
7. Applying good practice

TABLE II:
REPAIR TECHNIQUES FOR THE CURRENT PROJECT

Crack Repair Techniques 1. Preparation of surface. 2. Installation of injection 3. Mixing of epoxy 4. Injection of epoxy 5. Sealants of surface	**Spalling & Corrosion Repair Techniques** 1. Preparation of surface. 2. Installation of steel reinforcement jackets / corrosion incubation. 3. Application of PMM 4. Sealants of surface 5. Plastering of surface 6. Painting of surface
Staining Removal Techniques 1. Preparation of surface. 2. Removal of plants and green marks. 3. Clean the cracks	**Peeling & Dampness Removal Techniques** 1. Preparation of surface. 2. Remove the plastered surface 3. Apply PMM

4. Installation of injection 5. Mixing of epoxy 6. Injection of epoxy 7. Sealants of surface	4. Sealants of surface 5. Plastering of surface 6. Painting of surface

X. COST OF REPAIR

After per the investigation of Toilet and Store Room Region covering approx 26.4 m^2 Area the repair cost is tabulated below

TABLE III:
MARKET AVERAGES COST OF REPAIR (CPWD 2023)

Sr. No	Item Description	Unit	Rate (INR)	Qty	Amount (INR)
1	Surface preparation (plaster/tiles)	m^2	100	26.4	2,640
2	Crack repair (epoxy injection / sealant)	m	250	10	2,500
3	RCC spalling repair + reinforcement treatment	m^2	1,000	5	5,000
4	Waterproofing (toilet floor + walls up to 1.2 m)	m^2	450	15	6,750
5	Plumbing (pipe replacement + fittings)	Lump sum	—	—	6,000
6	Floor & wall tile replacement	^{2}	750	20	15,000
7	Replastering (internal/external walls)	m^2	250	20	5,000
8	Painting (anti-fungal emulsion)	m^2	100	25	2,500
9	Door/Window repairs or replacement	Lump sum	—	—	4,000
10	Miscellaneous & contingencies (10%)	—	—	—	4,940
	Total Estimated Cost				**₹54,330**

XI. CONCLUSION

The detail investigation was not required due to less damage in the structural and non-structural members. The overall cost of repair was approx. Rs 54,330 /-. The major reason of the distress was leakage in pipe networks. So some of the conclusions are as follows:

- Proper fitting of Drainage Pipes and sealing around the pipes at regular time period.
- Cleaning of interior and exterior structure at regular time period.
- Regular Maintenance & Repairing work like crack grouting plastering, painting etc. required.
- Proper Terrace Drain of water is essential.
- The life of structure is increased to 10 – 12 years.

Recommendation

During the service life of any structure, inspection and maintenance is required at a regular interval of 3 - 5 years. Research should be carried out for new innovative materials to bond between new and old concrete / masonry or other materials and restore its parameters.

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Examining the Role of User Experience and Interface Design in Digital Wallet Adoption: An Empirical Analysis

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Abstract: The world of payments has changed dramatically as a result of the quick development of financial technology, or FinTech, with digital wallets becoming a key component of the cashless economy. In the larger framework of the FinTech revolution, this study investigates the relationship between innovation, shifting consumer behavior, and the use of digital wallets. By assessing major technological, behavioral, and regulatory trends, the research shows the elements impacting user adoption, trust, security concerns, and post-adoption engagement. Understanding how digital wallets are changing user experience, financial inclusion, and convenience is emphasized. The paper intends to give a thorough overview of the potential and difficulties that digital wallet providers and users face in an increasingly digital financial ecosystem, drawing on current empirical findings.

Keywords: Digital Wallets, FinTech, Consumer Behavior, Cashless Economy, Technology Adoption

I. INTRODUCTION

The global financial landscape has undergone a paradigm shift in recent years, largely driven by rapid technological advancements and evolving consumer expectations. At the core of this transformation lies the financial technology (FinTech) revolution—an umbrella term that encompasses innovative financial services driven by technology. One of the most notable and widely adopted FinTech innovations is the digital wallet. Digital wallets, also known as e-wallets, are applications or platforms that allow users to conduct electronic transactions, store payment information, and manage funds securely through mobile devices or computers.

The digital wallet ecosystem is growing due to the demand for cashless, contactless, and real-time payments. Supported by governments, banks, and tech companies, platforms like Paytm, Google Pay, and Apple Pay are changing consumer behavior, especially in regions with high mobile use but limited banking. Adoption is driven by usefulness, ease, trust, security, and social influence. The COVID-19 pandemic further boosted digital wallet use. However, issues like user satisfaction, privacy, and regulations remain. This study explores adoption trends, user behavior, and the future impact of digital wallets in a cashless economy.

1.1. BACKGROUND OF THE STUDY:

Payment systems have evolved with society and technology, moving from barter and cash to digital wallets. These wallets became popular due to smartphones, internet access, and initiatives like Digital India. Once seen as high-tech tools, they are now widely used for fast, easy, and secure payments. FinTech has changed how finance works, with digital wallets offering features like one-click payments, QR codes, and rewards. In developing countries, they help include people without bank access. However, issues like security, regulation, and digital awareness remain. This study explores what drives people to adopt and keep using digital wallets as part of the move toward a cashless economy.

1.2. Definition of Digital Wallets

"A digital wallet, also referred to as an e-wallet, is a virtual platform or software that stores users' payment information, enabling them to make electronic transactions easily and securely". Essentially, digital wallets replace the need for carrying physical cash or credit cards, as they store payment credentials, such as credit/debit card numbers, bank account details, and digital currencies, on a mobile device or cloud-based platform (Liébana-Cabanillas et al., 2017). A key feature of digital wallets is their security measures, such as encryption, two-factor authentication (2FA), and biometrics (fingerprint, face recognition), which ensure the safety of transactions and protect users from fraud.

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1.2.1. Digital wallets can store several types of information:

- **Bank account details**: These are linked to the wallet to facilitate fund transfers and payments.
- **Credit and debit card information**: This allows users to make payments without entering card details every time.
- **Cryptocurrencies**: Some wallets are designed to store and manage digital currencies like Bitcoin, Ethereum, etc.
- **Identification data**: Some digital wallets also store IDs, allowing users to carry their identification digitally (e.g., government IDs, loyalty cards, etc.).

1.3. Scope of Digital Wallets

The scope of digital wallets extends far beyond simple payments, as these systems have evolved into comprehensive financial tools that offer a wide range of services. Originally designed to facilitate online shopping, digital wallets have now expanded into various domains, including retail, transportation, peer-to-peer (P2P) transfers, and even investment management.

- **Retail & E-Commerce:** Digital wallets enable consumers to save payment details for speedy online purchases, guaranteeing quicker checkout times and improved user convenience (Zhou, 2014).
- **In-Store Transactions:** Digital wallets allow contactless payments at real locations using Near Field Communication (NFC) and QR code technology. Wallets that are often used for in-store transactions include “Apple Pay, Google Pay, and Samsung Pay” (Liébana-Cabanillas et al., 2017).
- **Peer-to-peer Transfers:** With certain wallets, users can utilize their mobile devices to transmit money to friends, relatives, or acquaintances. P2P transfers frequently employ services like PayPal, Venmo, and Zelle (Kou et al., 2021).
- **Bills and Utilities**: Many digital wallets also offer features for users to pay bills (e.g., electricity, mobile phone bills) directly from the wallet, further enhancing their utility (Arora & Sandhu, 2018).
- **Integration with Financial Services:** Access to various financial services, including investment products, insurance, and loans, is now possible through digital wallets. Some wallets, for instance, let users manage mutual fund investments or purchase and sell cryptocurrencies (Gomber et al., 2018).
- **Financial Inclusion:** “Digital wallets have emerged as a crucial instrument for financial inclusion in areas with restricted access to conventional banking infrastructure. Digital wallets help marginalized groups by providing access to financial services via mobile devices (Suri & Jack, 2016).”

1.4. Role of Digital Wallets in a Cashless Economy

A cashless economy is one where financial transactions are conducted primarily through digital means, eliminating or reducing the use of physical cash. Digital wallets are key enablers of this transformation. They simplify daily transactions, reduce operational costs associated with handling cash, and allow better tracking of expenditures for both individuals and businesses (Arora & Sandhu, 2018).

In India, for instance, the move toward a cashless economy gained momentum after the 2016 demonetization and the launch of the Digital India initiative. Digital wallets like Paytm and PhonePe became household names, particularly for small-value retail transactions. Their integration with government services, merchant payments, and financial management tools further enhances their role in promoting a digital economy.

1.5. Innovation in Digital Wallets

Digital wallets have undergone continuous innovation, incorporating emerging technologies and offering enhanced features that contribute to a more seamless, secure, and personalized user experience. The key innovations are detailed below:

1.5.1. Integration of Emerging Technologies (e.g., Biometrics, Blockchain, AI): Digital wallets are increasingly integrating cutting-edge technologies to improve security, convenience, and functionality.

- **Biometrics**: The use of biometric authentication (e.g., fingerprint recognition, facial recognition) has become common in digital wallets to enhance security. Biometrics offer a higher level of authentication than traditional passwords or PINs, ensuring that only the authorized user can access and make transactions (Al-Khateeb et al., 2019).
- **Blockchain**: Blockchain technology is integrated into digital wallets to offer enhanced transparency, security, and immutability of transaction records. It enables secure, decentralized transactions and provides solutions for fraud prevention and ensuring data integrity (Narayanan et al., 2016).
- **Artificial Intelligence (AI)**: AI is utilized in digital wallets to personalize user experiences, analyze transaction patterns, and detect fraud. AI can predict user preferences and offer tailored recommendations for payments, promotions, or rewards (Gomber et al., 2018).

1.5.2 Interoperability with Banking and Non-Banking Platforms: Interoperability refers to the ability of digital wallets to work seamlessly with both banking and non-banking platforms, making them highly versatile and accessible for a wide range of users. This integration ensures that users can transfer funds, make payments, or access services across different platforms and financial institutions without compatibility issues. For example, users can link their digital wallet to traditional bank accounts, peer-to-peer payment systems, or even crypto currency platforms, allowing for a unified and comprehensive financial ecosystem. This also includes integration with non-financial services like retail or utility bill payments, further improving the convenience of digital wallets (Kou et al., 2021).

1.5.3. Personalization and User-Centric Design Digital wallets are evolving to become more user-centric, with personalization playing a significant role in improving customer experience. By using data analytics and AI, digital wallets can tailor their interface, services, and product offerings to suit individual preferences. For example, digital wallets may provide customized offers, discounts, or loyalty rewards based on a user's transaction history, location, or interests. Furthermore, some wallets allow users to customize their dashboards, choosing the layout, favorite payment methods, and preferred currency options (Liébana-Cabanillas et al., 2017). This level of personalization encourages deeper user engagement and enhances overall satisfaction.

1.5.4. Use Cases in Retail, Transport, E-Commerce, and P2P Transfers: Digital wallets have diverse use cases across various industries, expanding their role beyond simple mobile payments:

- **Retail**: Digital wallets allow consumers to make quick and secure payments at both physical and online stores. With contactless technology like NFC (Near Field Communication), customers can make in-store purchases with a simple tap of their mobile devices, minimizing waiting times and enhancing the overall shopping experience.
- **Transport**: In the transport sector, digital wallets are used for ticketing, fare payments, and real-time tracking. For example, apps like Google Pay and Apple Pay integrate with public transportation systems, allowing commuters to pay bus or metro fares digitally (Zhou, 2014).
- **E-Commerce**: In online shopping, digital wallets expedite the checkout process, enabling secure and fast transactions. They often store multiple payment methods, which makes them convenient for users who shop frequently (Arora & Sandhu, 2018).
- **P2P Transfers**: Digital wallets also enable "peer-to-peer (P2P)" transfers, allowing users to send money to friends or family instantly. Platforms like Venmo, PayPal, and Cash App are commonly used for P2P transactions, making it easy for users to split bills or pay for services without needing to handle cash.

II. OBJECTIVES OF STUDY

1. To examine the main elements impacting consumers' adoption of digital wallets.
2. To investigate how cutting-edge technologies like blockchain, AI, and biometrics are promoting innovation in digital wallets.
3. To examine the impact of digital wallets on consumer behavior in the context of convenience, security, and trust.
4. To assess the challenges and barriers faced by consumers and businesses in adopting digital wallet technologies.
5. To evaluate the future trends and potential of digital wallets in contributing to the growth of a cashless economy.

III. SCOPE OF THE STUDY

This study focuses on exploring the role of digital wallets in the growing FinTech revolution, particularly in the context of a cashless economy. It covers the adoption of digital wallets in both developed and emerging markets, with an emphasis on new technologies like biometrics, blockchain, and artificial intelligence (AI). The research will examine how these technologies influence consumer behavior, including factors like trust, security, and ease of use. It will also look at the use of digital wallets across industries such as retail, e-commerce, transportation, and peer-to-peer payments. The study will cover trends up until 2025, aiming to understand the future potential of digital wallets in shaping a cashless society.

IV. LITERATURE REVIEW

Digital wallets have emerged as a critical component of the FinTech revolution, facilitating cashless transactions and offering consumers a more convenient and secure alternative to traditional payment methods. The increasing adoption and innovation in digital wallets have transformed financial ecosystems globally. This literature review examines the adoption factors, innovative technologies shaping digital wallets, and the consumer behavior that influences their use.

The uptake of digital wallet technology

Digital wallet adoption has been extensively examined using technology acceptance models, with a focus on perceived security and convenience of use (Zhou, 2014). According to Davis (1989), perceived utility is still a major factor in consumer adoption; people are more inclined to embrace digital wallets if they believe they are safe and convenient. According to another research by Liébana-Cabanillas et al. (2017), adoption is significantly hampered by the perceived danger of fraud; however, these worries are being allayed by the increasing integration of security measures like biometrics. Additionally, building customer confidence in mobile payment systems requires technological dependability and trust in financial institutions (Gomber et al., 2018).

A. Advancements in Digital Wallets

The incorporation of cutting-edge technology like blockchain, artificial intelligence (AI), and biometrics has sparked innovation in digital wallets. While blockchain is transforming payment systems by offering decentralized transaction verification, which ensures transparency and lowers costs, biometric authentication techniques like fingerprint and facial recognition are improving security (Narayanan et al., 2016). According to Gomber et al. (2018), artificial intelligence has been essential in enhancing digital wallet platforms' fraud detection, customer assistance, and personalized offerings. Additionally, users can utilize digital wallets across a variety of industries, including retail, transportation, and healthcare, thanks to the interoperability between banking and non-banking systems, which further increases their usefulness (Kou et al., 2021).

B. Consumer Patterns in the Use of Digital Wallets

For digital wallets to be successfully adopted and used, consumer behavior is essential. Perceived risk, particularly with regard to security and privacy, has a major influence on consumers' readiness to accept mobile payment technologies, claim Liébana-Cabanillas et al. (2017). However, higher adoption rates have been attributed to growing confidence in these technologies, which has been fueled by improvements in security features (Arora & Sandhu, 2018). According to Zhou (2014), social influence also affects consumer choices because people are more inclined to use digital wallets after seeing their friends use them. Additional elements that influence customer behavior toward the adoption of mobile payment solutions are the convenience and ease of use offered by digital wallets (Zhou, 2014).

C. Future Trends and Implications of Digital Wallets

Digital wallets' future depends on their ongoing development and incorporation into the larger cashless economy. Mobile payments are essential for promoting financial inclusion, especially in areas with restricted access to traditional banking services, as Suri and Jack (2016) point out. Digital wallets increase total economic participation by providing unbanked persons with a means of interacting with the financial system. Additionally, it is anticipated that digital wallets would be crucial in decreasing reliance on currency, simplifying financial transactions, and improving productivity (Arora & Sandhu, 2018). Digital wallets' growing popularity across a range of industries and their capacity to provide individualized experiences are probably going to propel their uptake in the future and have an impact on the development of the financial sector.

V. RESEARCH METHODOLOGY

A quantitative research methodology will be used in the study to evaluate consumer behavior, innovation, and uptake of digital wallets in the North Gujarat region. Data on the main determinants of digital wallet usage, including security, convenience, and user experience, will be gathered using a descriptive research design. Convenience sampling was used to choose 150 respondents, the target sample size, in order to guarantee a wide representation of people who use or are aware of digital wallet services. The main instrument for gathering data will be a standardized questionnaire that asks about demographic information, adoption-influencing factors, security perceptions, and the function of cutting-edge technology like "biometrics and AI." Both in-person interviews and online surveys will be used to gather the data, making it accessible to the region's diverse population. Before being distributed widely, the questionnaire will go through a pilot test to guarantee validity and reliability. Inferential statistics like regression analysis will be used to look at relationships between various variables, while descriptive statistics will be used to summarize the responses. The study will help understand consumer behavior in the changing cashless economy and offer insightful information about the factors that promote or impede the adoption of digital wallets in North Gujarat.

VI. DATA ANAYSIS & INTERPRETATION

TABLE I:
DEMOGRAPHIC ANALYSIS

Demographic Variable	Category	Frequency (N=150)	Percentage (%)
Gender	Male	90	60.0%
	Female	60	40.0%
Age Group	18–25 years	45	30.0%
	26–35 years	55	36.7%
	36–50 years	35	23.3%
	50+ years	15	10.0%
Occupation	Student	40	26.7%
	Working Professional	60	40.0%
	Business Owner	30	20.0%
	Others	20	13.3%
Income Level (Monthly)	Below Rs.20,000	35	23.3%
	Rs.20,000 – Rs.50,000	45	30.0%
	Rs.50,000 – Rs.1,00,000	40	26.7%
	Above Rs.1,0,000	30	20.0%

TABLE II:
DESCRIPTIVE ANALYSIS

<table>
<tr><td rowspan="3">1</td><td rowspan="3">Digital Wallet Usage</td><td>Response</td><td colspan="2">Frequency (N=150)</td><td>Percentage</td></tr>
<tr><td>Yes</td><td colspan="2">135</td><td>90%</td></tr>
<tr><td>No</td><td colspan="2">15</td><td>10%</td></tr>
<tr><td rowspan="5">2</td><td rowspan="5">Digital Wallet Platforms Used :(Multiple Responses Allowed)</td><td>Platform</td><td colspan="2">Frequency</td><td>Percentage of Respondents</td></tr>
<tr><td>Google Pay</td><td colspan="2">110</td><td>73.3%</td></tr>
<tr><td>PhonePe</td><td colspan="2">95</td><td>63.3%</td></tr>
<tr><td>Paytm</td><td colspan="2">80</td><td>53.3%</td></tr>
<tr><td>Others</td><td colspan="2">20</td><td>13.3%</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">Adoption Factors (Likert Scale: 1–5)</td><td>Factor</td><td colspan="2">Mean Score</td><td>Standard Deviation</td></tr>
<tr><td>Security</td><td colspan="2">4.3</td><td>0.7</td></tr>
<tr><td>Ease of Use</td><td colspan="2">4.2</td><td>0.8</td></tr>
<tr><td>Promotions/Discounts</td><td colspan="2">3.9</td><td>0.9</td></tr>
<tr><td rowspan="5">4</td><td rowspan="5">Awareness of Emerging Technologies</td><td>Technology</td><td colspan="2">Response</td><td>% Aware</td></tr>
<tr><td></td><td>Yes</td><td>No</td><td></td></tr>
<tr><td>Biometric Authentication</td><td>120</td><td>30</td><td>80%</td></tr>
<tr><td>Blockchain</td><td>60</td><td>90</td><td>40%</td></tr>
<tr><td>Artificial Intelligence</td><td>85</td><td>65</td><td>56.7%</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">Perceived Benefits – Convenience</td><td>Response</td><td colspan="2">Frequency (N=150)</td><td>Percentage</td></tr>
<tr><td>Yes</td><td colspan="2">128</td><td>85.3%</td></tr>
<tr><td>No</td><td colspan="2">22</td><td>14.7%</td></tr>
<tr><td rowspan="6">6</td><td rowspan="6">Barriers to Adoption (Multiple Responses Allowed)</td><td>Barrier</td><td colspan="2">Frequency</td><td>Percentage of Respondents (N=150)</td></tr>
<tr><td>Security concerns</td><td colspan="2">45</td><td>30%</td></tr>
<tr><td>Lack of trust in digital platforms</td><td colspan="2">30</td><td>20%</td></tr>
<tr><td>Poor internet connectivity</td><td colspan="2">50</td><td>33.3%</td></tr>
<tr><td>Lack of awareness of features</td><td colspan="2">40</td><td>26.7%</td></tr>
<tr><td>None</td><td colspan="2">35</td><td>23.3%</td></tr>
</table>

The demographic profile of the 150 respondents reveals that digital wallet usage is predominantly driven by young, male, working professionals belonging to the middle-income group in the North Gujarat region. The highest usage is observed among individuals aged 26–35 years, followed by students and business owners, indicating strong adoption among economically and digitally active users. Additionally, a majority of users fall within the Rs.20,000 to Rs.1, 00,000 income bracket, reflecting a growing acceptance of digital wallets among the middle-income population. Overall, the findings suggest that digital literacy, age, occupation, and income play a significant role in influencing digital wallet adoption.

Descriptive Analysis:

respondents reported using digital wallets, indicating strong adoption within the surveyed population in North Gujarat. Google Pay is the most widely used platform, followed by PhonePe and Paytm. A small segment also uses other digital wallets, indicating a preference for major players in the region. Security and ease of use are the most influential adoption factors. Trust is also rated high, while promotions play a slightly lesser role but still contribute significantly to usage decisions. Most users are aware of biometric authentication, indicating familiarity with secure access features. However, awareness of blockchain and AI remains moderate, pointing to a knowledge gap in advanced technology integrations. A large majority believe digital wallets are more convenient than traditional payment methods, reinforcing their growing relevance in daily transactions. Internet connectivity and security concerns are the leading barriers to adoption. Interestingly, 23.3% reported no major issues**,** showing an overall smooth experience for many users.

TABLE III:
RELIABILITY TEST – CRONBACH'S ALPHA

Test	Value
Cronbach's Alpha	0.812
No. of Items	4

(***Source:*** SPSS 27.0)

Cronbach's Alpha = 0.812**,** indicating good internal consistency among the adoption factor items. Values > 0.7 are acceptable in social science research

TABLE IV:
ANOVA – COMPARISON BY AGE GROUP

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.73	3	1.91	4.25	0.007**
Within Groups	65.22	146	0.45		
Total	70.95	149			

(***Source:*** SPSS 27.0)

With p = 0.007 < 0.05, the ANOVA test reveals a statistically significant difference in trust levels across different age groups.

Chi-Square Test – Gender vs. Digital Wallet Usage

TABLE V:
CROSS-TABULATION:

Gender	Uses Wallet (Yes)	Does Not Use (No)	Total
Male	85	5	90
Female	50	10	60
Total	135	15	150

(***Source:*** SPSS 27.0)

TABLE VI:
CHI-SQUARE OUTPUT:

Test	Chi-Square Value	df	Sig. (p-value)
Pearson Chi-Square	6.32	1	0.012**

(***Source:*** SPSS 27.0)

With p = 0.012, there is a significant association between gender and digital wallet usage, implying males are slightly more likely to adopt digital wallets.

VII. FINDINGS

- 90% of respondents use digital wallets, showing high adoption in the North Gujarat region.
- Google Pay is the most used platform, followed by PhonePe and Paytm.
- Key factors influencing adoption are security, ease of use, and trust in the platform.
- Most users know about biometric features; fewer are aware of blockchain and AI integration.
- Users find digital wallets more convenient than cash or cards.
- Users generally trust digital wallet security but some still have concerns about privacy and cyber threats.
- Challenges include internet issues, security concerns, and lack of awareness of full features.
- Younger users (18–35 years) are the most active users; males slightly outnumber females in adoption.

VIII. CONCLUSION

The study highlights that digital wallets have become a vital component of the FinTech revolution, especially in the ongoing shift toward a cashless economy. With the widespread use of smartphones and increasing internet accessibility, digital wallets are no longer a luxury but a necessity for modern financial transactions. The findings reveal a high adoption rate among users, driven mainly by convenience, security, and trust in platforms.

Innovation in digital wallets—through features like biometric security, instant payments, and rewards—has further enhanced user experience and engagement. However, the study also points to key challenges such as limited awareness of advanced technologies, digital literacy gaps, and security concerns that need to be addressed for broader inclusion and sustained usage.

In conclusion, digital wallets are transforming how consumers interact with money. Their continued success depends on technological advancement, user trust, and strategic efforts by FinTech firms and policymakers to promote safe, inclusive, and user-friendly financial ecosystems.

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A Investigative Review on Energy Efficient Utilization in Virtual Machine Allocation

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Abstract: This study has carefully analyzed and categorized the objectives, varieties, working principles, benefits, limitations, and simulation tools of existing energy-efficient scheduling algorithms. Our systematic and comprehensive study will enhance the fundamental understanding of energy-efficient techniques for new scholars who wish to delve deeper into the energy sector. This evaluation highlights how crucial it is to distribute virtual machines (VMs) in an energy-efficient way to reduce data centers' environmental impact and running costs. It provides useful information for researchers, practitioners, and policymakers who want to develop and implement long-term strategies for optimizing resource utilization in cloud and edge computing environments. To sum up. Load balancing systems aim to distribute workload evenly across physical servers to prevent resource underutilization and overload situations and reduce energy wastage. Consolidation solutions integrate virtual machines (VMs) onto fewer physical servers in an effort to optimize resource allocation. As a result, less power is used and the server is used more. Migration solutions lower energy consumption while preserving performance levels through the use of dynamic virtual machine reallocation. By considering energy consumption indicators, task characteristics, and resource availability, scheduling algorithms aim to allocate resources as efficiently as feasible.

Keywords: Energy efficiency, Resource management, Cloud computing, Workload consolidation, Virtual machine migration.

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I. INTRODUCTION

Due to the significant rise in energy consumption brought on by the expanding need for computational power in data centers, energy efficiency has emerged as a critical issue. Virtualization technology, in particular virtual machine (VM) allocation, is crucial for enhancing resource utilization and reducing energy usage in data centers. This paper offers a comprehensive review of research projects and methods aimed at achieving energy-efficient use through virtual machine allocation algorithms.

The demand for processing resources in data centers has expanded considerably due to the speedy development of digital services and the adoption of data-intensive apps. In addition to performance and scalability problems, this growing demand raises significant concerns about energy use and environmental sustainability. Data centers, which are the backbone of modern computing infrastructure, are notorious for using enormous amounts of energy, increasing running costs and releasing carbon dioxide into the sky.

The inherent inefficiencies present in traditional data center architectures have been demonstrated to be mitigated by the use of virtualization technologies, particularly virtual machine (VM) allocation. Software can be isolated from physical hardware and virtualized resources can be dynamically provisioned through the VM allocation process, which enhances resource usage and energy efficiency. Allocating virtual machines (VMs) in a way that optimizes energy efficiency, however, poses a number of challenging issues that require in-depth research and innovative thinking.

This is how the rest of the document is organized: Section II describes the various algorithms used in cloud computing. Section III contains related work. Section V provides the conclusion, and Section IV includes Open Research Issues.

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II. DIFFERENT CLOUD COMPUTING ALGORITHMS

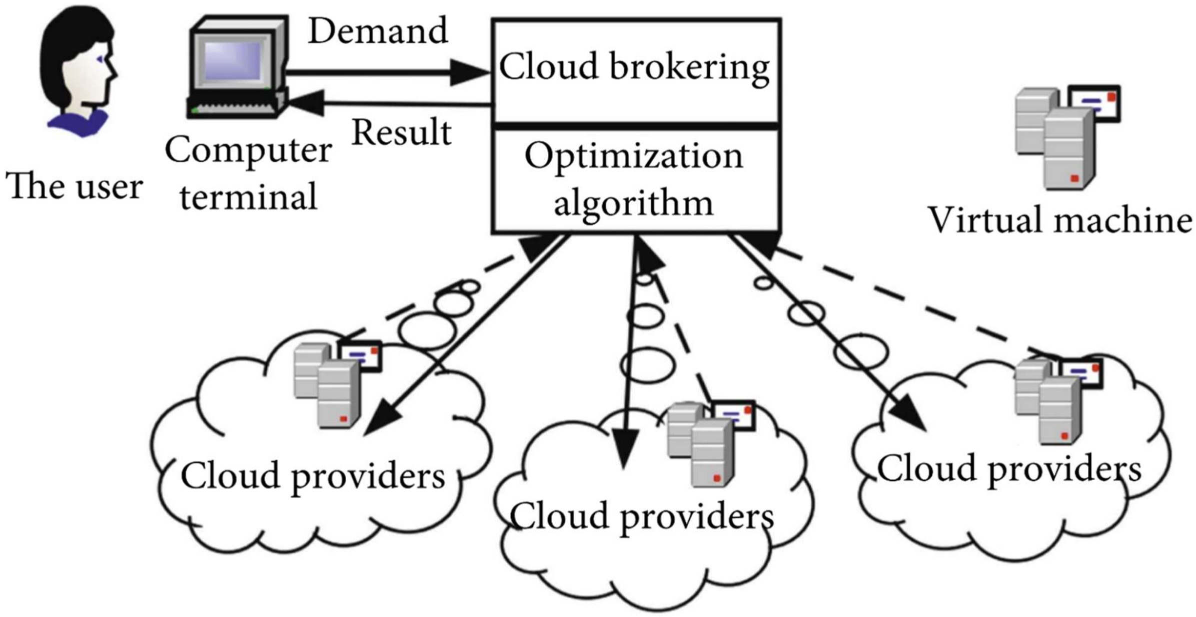

Fig. 1 VM resource allocation in cloud computing.[2]

2.1. Modified Hummock Algorithm [4]

In order to reduce virtual machine energy consumption, the Modified Ant Colony Optimization (MACO) technique was created within a cloud computing framework. In order to improve the quality of the results, MACO, which was initially created to solve the traveling salesman problem, added a solution reconstruction method. MACO successfully reduced the problem of path overlap by making sure that all ants released pheromones and responded to pheromone levels while navigating. Each ant was able to successfully finish its path-finding process thanks to the pheromone management mechanism, which eventually increased convergence rates. The strategy also aimed to lower operating expenses and energy consumption while improving overall performance.

2.2. First Fit Decreasing Algorithm [4]

Items are assigned to the first available bin using the First-Fit Decreasing (FFD) algorithm, which arranges them in a non-increasing order. By optimizing the number of physical machines (PMs), this technique can increase their utilization and lower power consumption. Two variants of FFD—the FFD mean and the FFD median—can be used in conjunction with Vector Bin Packing (VBP) methods for Virtual Machine Placement (VMP) in cloud computing. FFD explains the container Packing Problem (BIP), which involves gathering a container and a collection of items. Virtual machines (VMs) ought to be stacked in a downward array based on size prior to FFD. Each and every virtual machine (VM), beginning with the most important one, must be located in physically accessible machines (PM) that can be kept in good working order. Until not all virtual machines are deployed, the procedure will keep going.

2.3. Exchange Strategies for Multiple Ant Colony System [4]

This method uses a graphical layout to map potentially linked virtual machines. The OEMACS algorithm is used to find the best mapping solution after each virtual machine has been mapped across a single server. Placement, migration, and selection are the three phases of virtual machine consolidation. OEMACS uses the TSP, which offers the quickest route for migration and placement, in accordance with graph theory.

2.4. PSO (Particle Swarm Optimization)-based Scheduling

Cloud computing virtual machine (VM) allocation based on scheduling based on Particle Swarm Optimization (PSO). The objective function should reflect the optimization goal, such as optimizing resource use or reducing energy use, depending on the specific requirements of the cloud computing environment. To achieve optimal performance for a given problem instance, tuning and experimentation may be required to modify parameters like search space bounds, inertia weight, and cognitive and social learning aspects. This technique provides a framework for deploying PSO-based scheduling for virtual machine (VM) allocation in cloud computing settings, facilitating efficient resource and energy consumption management. PSO is a nature-inspired metaheuristic algorithm that mimics the social behavior of bird flocking or fish schooling to find an optimal solution. It is used in cloud computing to optimize VM placement by minimizing energy consumption, cost, or resource wastage. Each particle in the swarm represents a potential solution (a VM placement strategy).Particles move in the solution space based on their own best-known position and the swarm's best-known position. The movement is influenced by two factors: personal experience (pBest) and global experience (gBest) to converge towards an optimal VM allocation strategy. The objective is to optimize a given function, such as minimizing power consumption or maximizing resource utilization.

III. ENERGY-EFFICIENT AND SECURE VM ALLOCATION STRATEGIES

3.1 Dynamic VM Consolidation

Dynamic VM consolidation involves migrating VMs to fewer physical hosts to reduce power consumption while ensuring minimal service disruption. Techniques include:
Threshold-based Consolidation: Uses CPU and memory utilization thresholds to trigger VM migrations.
AI-Based Consolidation: Implements machine learning algorithms to predict VM usage patterns and optimize migration decisions.
Energy-Aware Migration: Considers energy metrics when deciding which VMs to migrate, reducing unnecessary power usage.

3.2 Secure Load Balancing Techniques

Efficient load balancing ensures that VMs are allocated optimally across servers while maintaining security and energy efficiency.
Trust-Based Load Balancing: Assigns workloads based on VM trust scores to prevent compromised nodes from hosting critical applications.
Energy-Aware Load Balancing: Uses power consumption models to allocate resources dynamically.
AI-Driven Approaches: Reinforcement Learning (RL) and Deep Learning (DL) models optimize workload distribution in real-time, ensuring secure resource allocation.

3.3 Attack Mitigation in VM Allocation

Cloud environments face threats such as DDoS attacks, VM escape attacks, and side-channel attacks, requiring proactive mitigation techniques.
Intrusion Detection Systems (IDS): AI-based IDS detects unusual VM behavior in real-time, flagging potential security breaches.
Blockchain-Based Security: Decentralized authentication prevents unauthorized access and tampering with VM allocations.
Isolation-Based Strategies: Using sandboxing and hardware-level isolation (Intel SGX, AMD SEV) to prevent VM escape attacks.

3.4 AI and Machine Learning for Secure and Energy-Efficient VM Optimization

Machine learning enhances energy efficiency by predicting workload demands and optimizing allocation in real time while improving security measures.
Predictive VM Scaling: Uses historical data to anticipate peak demand and preemptively allocate resources.
Reinforcement Learning for Energy Efficiency: Adaptive algorithms learn optimal VM placement strategies over time.

Anomaly Detection: AI-driven methods detect inefficient or compromised VMs consuming excessive power, improving both efficiency and security.

3.5 Green Computing and Sustainable Cloud Practices

Green computing focuses on minimizing energy consumption by leveraging renewable energy and eco-friendly data center designs.
Renewable Energy Integration: Allocates VMs to data centers powered by solar or wind energy. Carbon-Aware Scheduling: Shifts workloads to regions with lower carbon footprints. Energy-Proportional Computing: Uses power-efficient hardware to scale power consumption dynamically.

IV. RELATED WORK

4.1 Power-Aware scheduling [1]

In [1], The authors place a high priority on effective resource allocation in order to reduce energy consumption in cloud-based systems. This study investigates a number of energy-saving techniques and algorithms, such as power-aware scheduling, virtual machine migration, and dynamic workload consolidation. It emphasizes how important it is to incorporate performance metrics and energy efficiency when making decisions about resource management. The suggested methods seek to maintain Quality of Service (QoS) and cost-effectiveness while lowering energy waste and carbon emissions. The results of the study show that methods like power-aware scheduling, workload consolidation, virtual machine migration, and dynamic resource provisioning can efficiently maximize resource use and reduce energy consumption.

Merits- These techniques offer a number of benefits, including reduced expenses, a reduced carbon footprint, and enhanced efficiency. Offer several significant benefits, including reduced expenses, a reduced carbon footprint, and increased overall effectiveness.
Demerits- More attention needs to be paid to challenges including complexity, scalability, and implementation issues.

4.2 MBFD and SI based Grasshopper Technique [2]

In [2], The Modified Best Fit Decreasing (MBFD) algorithm has been used to effectively assign virtual machines (VMs) to the best host. In order to improve VM selection, this study presents a novel Grasshopper Optimization Algorithm (GOA) based on swarm intelligence. The suggested framework provides a reliable way to lower cloud data centers' overall energy usage. The method reduces energy consumption and migration frequency by optimizing resource utilization in virtual machines (VMs) for real-world applications. Furthermore, the GOA ensures the best VM selection while reducing problems associated with SLA violations and improper migrations. The "VM Migration" method entails assigning the virtual machines (VMs) to the appropriate PM at the outset and then requiring their migration in accordance with requirements. The efficiency with which the hosts and virtual machines (VMs) use their resources determines the allocation strategy. To minimize energy consumption during migration, the proposed MBFD method continuously updates the lowest power requirement for allocating or migrating a virtual machine across a host

Merits: By using the MBFD algorithm and GOA, the suggested method outperforms conventional techniques like ABC, E-ABC, and CS in terms of lowering energy consumption, minimizing SLA violations, and lowering the number of migrations.
Demerits: To develop the proposed framework and achieve differentiated performance on a limited number of hosts (10 hosts deploying 103 VMs), the authors plan to conduct additional research in the near future involving a bigger number of hosts and virtual machines (VMs).

4.3 Peak Efficiency Aware Scheduling (PEAS) [3]

In [3], The authors create the measurements of peak power efficiency and optimal usage for actual equipment. We also calculate the minimal number of Compute Resource Units (CRUs) a PM should supply in order to achieve optimal power efficiency through performance quantification using CRUs. Peak Efficiency Aware Scheduling (PEAS) is a new virtual machine consolidation technique. Peak Efficiency Aware Placement (PEAP) and Peak Efficiency Aware Cost-effective Reallocation (PEACR) are the two algorithms that make up PEAS. For each virtual machine, PEAP chooses the best host based on the three previously mentioned ideas. The task of reassigning virtual machines from overworked and unproductive hosts falls to PEACR. Comprehensive tests were conducted on CloudSim to evaluate PEAS's performance in relation to several baseline algorithms, such as TVRSM and PABFD.

Merits: PEAS keeps running computers running at less than maximum capacity whenever possible in order to maximize the power efficiency of servers. A variety of VM placement and migration algorithms and techniques, including TVRSM and PABFD, were used to assess PEAS. According to experimental findings, PEAS efficiently lowers cluster energy consumption, shortens the typical job execution time, and enhances a number of QoS metrics.

Demerits: In edge computing and fog computing, two domains that are expanding quickly and presenting related difficulties, the author plans to investigate the optimization of task scheduling and resource provisioning. In order to facilitate proactive resource allocation and virtual machine consolidation in intricate cloud systems, we will also focus on using machine learning to profile and predict job workloads and measure power consumption at the virtual machine level.

4.4 The OEMACS Algorithm [4]

In [4], The authors discuss the Order Exchange and Migration Ant Colony System's operation and results. The Clouds simulator is used to solve various Virtual Machine Placement issues in various scenarios. Of the nine cases, FFD employs the most physical servers, while OEMACS uses the fewest. Furthermore, it is observed that the VMP through OEMACS is remarkably quick. Other trials conducted in various situations and environments have shown that the OEMACS has the highest number of good findings when compared to other algorithms.

Merits- The OEMACS algorithm has allowed us to save energy by turning off servers that aren't in use. It is also completed very efficiently and in little time.
Demerits- For optimal efficacy, researchers in this field may employ the newest techniques and algorithms.

4.5 Intelligent Mine Blow Optimization (IBMO) technique [5]

In [5], The objective of this study is to develop an artificial intelligence (AI)-driven virtual machine (VM) allocation model for cloud load balancing that prioritizes security and energy efficiency. A key contribution of this work is the introduction of the Intelligent Mine Blow Optimization (IBMO) technique, designed to securely allocate VMs in the cloud. This method also mitigates security threats posed by attacks on virtual machines from various users. The study evaluates the performance of the proposed IBMO-based VM allocation model by comparing it against other approaches using multiple assessment metrics. The analysis of the results demonstrates that the proposed method outperforms existing alternatives. Notably, the suggested approach reduces SLA violations by an average of 50% and achieves a 60% reduction in energy consumption. By significantly lowering energy usage in cloud data centers, this method contributes to advancing green computing. IBMO is an enhanced version of binary multi-objective optimization tailored for discrete problems like VM placement. It extends classical binary optimization techniques by improving the way multiple objectives are handled.The algorithm encodes VM-to-host assignments in binary form.It uses multi-objective optimization techniques to find trade-offs between factors like energy efficiency, load balancing, and QoS (Quality of Service).Improvements over basic binary optimization include dynamic mutation strategies, adaptive weight adjustments, and better exploration-exploitation balance.

Merits- The three primary benefits of the suggested IBMO technique are enhanced exploration, fewer iterations to find the best solution, and global searching capability. When compared to the most recent state-of-the-art techniques, the effectiveness of the suggested secure and energy-efficient virtual machine allocation model is demonstrated by the validation of the optimization-based scheduling mechanism's results in terms of energy consumption, SOA violations, number of PMs used, and execution time during performance analysis.
Demerits- By putting into practice an improved security method for detecting and preventing cloud system attacks, this work can be expanded.

4.6 The Grey Model in Traffic Burst (GMTB)[6]

In [6], The researchers have introduced a resource management system utilizing an arrival model switching mechanism to enhance energy efficiency in cloud data centers. This study examines cloud task characteristics and presents two distinct task arrival models. The Grey Model in Traffic Burst (GMTB) is applied in burst scenarios, whereas the Poisson process-based arrival model is used under normal conditions. To facilitate model switching and detect anomalies, an anomaly detection module is incorporated. The proposed approach includes an effective task arrival switching technique that addresses both workload prediction and anomaly event detection. By leveraging the Poisson process-based arrival model and the GMTB model, this method provides reliable predictions for various cloud task arrival scenarios.

Merits- A virtual machine (VM) migration strategy based on utilization and a Service Level Agreement (SLA)-aware power management policy is proposed to enhance energy efficiency.
Demerits- To ensure the effectiveness of load forecasting and energy-efficient scheduling algorithms in a distributed cluster, thorough testing in a real-world environment is necessary.

4.7 GDR and MPC [7]

In [7], Reducing energy consumption in cloud systems is the main goal of many energy-conscious strategies now in use. Two models are suggested here: the maximum percentage of correlation (MPC) and the gradient regression-based method (GDR). These models can dramatically reduce cloud computing energy consumption while preserving required performance levels when evaluated in a cloud data center using the CloudSim simulator. According to the simulation results, (1) the Gdr host overloaded detection method works better in terms of energy usage than the MCP approach, and (2) it is more beneficial to take CPU, memory, and internet traffic into account when choosing virtual machines (VMs) from an overloaded host.

Merits- The GDR and MPC can significantly lower the energy usage of cloud computing..
Demerits- The SLA breach is a serious problem from the customer's point of view. A more efficient method that lowers the SLA violation can be offered in the future because, in this instance, the SLA violation tends to rise as energy usage decreases.

4.8 Polymorphous Energy Efficient Resource Allocation Approach (PEERA) [8]

In [8], A polymorphous energy efficient resource allocation approach, or PEERA, is proposed to enhance energy and performance measures such as energy consumption, make span, and resource usage. To maximize the dynamic allocation of resources, a method for reducing the amount of time required to complete each activity is described. To shorten the Make span and save energy, an extra operation is added to the algorithm that caches a subset of the best solutions at each iteration. The PEERA has been contrasted with the Particle Swarm Optimization (PSO) method and the Multiverse Optimizer (MVO) algorithm. The findings were computed using standard data sets and the virtual machines were left in their original configurations. With the following settings, CloudSim 3.0 produced the following results: VM = "10, 20, 30, 40, 50, 60" and tasks = "100, 200, 300, 400, 500, 600."

Merits- It is evident that the PEERA yields better results in terms of resource utilization, energy efficiency, and makespan. In addition to optimizing Makespan, it makes intelligent use of resources while using less energy.
Demerits- More research is required on energy efficiency, reducing energy consumption, and more efficient use of resources.

4.9 VMRRU Technique [9]

In [9], The use of the Virtual Machine Energy Resource Request Utilization (VMERRU) Advanced Algorithm is suggested. This method allocates data centers (DC) and virtual machines (VM) based on factors such as resource consumption levels, energy monitoring, input request demands, and matching criteria. As a result, an effective request processing method based on parallel computing is proposed. This method enhances request prediction by utilizing request analysis, consumption estimation, and finally the state of available resources. An appropriate scheduling technique is suggested by utilizing multiple factors and processing them concurrently. The Cloud Simulation The technique is implemented in Java and is simulated using the Cloud Analyst simulator. The simulation results demonstrate the effectiveness of the proposed algorithm in comparison to existing methods such as Round Robin and the Throttled approach for cloud component scheduling. Additionally, the study outlines the algorithm's implementation and the configuration of each component.

Merits- Calculating calculation time, computation cost, and energy utilization determines how efficient the outcomes are.
Demerits- Using the right architecture to store and retrieve data efficiently while working with input data utilization and storage.

4.10 AI model automatic training and deployment scheme based on K8S Architecture [10]

The researchers present an automated platform designed for training and deploying AI models, handling data processing, annotation, model training optimization, and publishing. Built on a cloud-edge architecture, the proposed system can generate customized models based on room environments while ensuring consistency and automation in model training, making it highly suitable for large-scale data center applications. Simulation and experimental results indicate that the system can manage multiple training tasks simultaneously and reduce the training time for a single model by 76.2%. The first experiment compares the time required for AI-based automatic training versus manual training using the same dataset, while the second evaluates the training time for different data volumes in AI-based automatic training.

Merits: this method, Additionally, it supports the execution of tasks concurrently. Thus, this approach can be used to improve the efficiency of model training and deployment. Consequently, the intelligent support provided by this proposed solution can be advantageous to the green data center.
Demerits- Despite efforts to save energy, the full environmental impact, including the manufacturing and disposal of edge devices, should be considered.

4.11 Maximum-Minimum Round-Robin algorithm (MMRR)[11]

In [11], The cloud services were significantly improved by the suggested hybrid strategy of using the Maximum Minimum load balancing algorithm in conjunction with Round Robin.The maximum and minimum constraints that typically prevent jobs with the shortest completion times from being completed on schedule will be resolved by the suggested hybrid. On the other hand, the task that takes the longest to complete will be completed first. Round robin that distributes work without regard to priorityThe data center's processing time is good for both MMRR (0.57ms) and Throttled (0.50ms), but it was worse for Round Robin (1.48ms). With an overall reaction time of 227.26 ms and an 89% cost-effectiveness rating, MMRR outperformed the other algorithms that were assessed. Therefore, in order to increase customer happiness, the study suggests that MMRR be included in cloud services.

Merits - The data center's processing speed is above average, the response time is promising, and using the new method to process a work is less expensive than using other algorithms.
Demerits- Future iterations of this study would use alternative quality of service (QOS) requirements, such as cost, throughput, and delay, for different routing policies. To determine which algorithm would produce the greatest results in the cloud environment, more data centers, users, and algorithms will be deployed.

4.12 Shortest Queue of d with Randomization and Round robin(SQ-RR(d))[12]

In [12], The authors' task is to suggest an alternative algorithm that enhances the results of the traditional power of two choices technique. Additionally, d servers are chosen using the new algorithm, though not entirely at random. The other d 1 servers are picked at random, while one server is chosen in a round robin method. The job is then routed to the server that has the fewest jobs. In the new algorithm, we use round-robin selection in conjunction with randomization to provide static load balancing. According to a theoretical approximation of this method, the new version performs better than the classical solution in every scenario, including systems operating at 99% capacity.

Merits- The theoretical approximation made in the paper is demonstrated by the simulations supplied by the authors. These simulations also demonstrate that for high service rates, there is a 60% greater chance of selecting an empty server.
Demerits- Given the enormous potential and long-term advantages, cloud service providers should also fund research.

4.13 Software Defined Networking (SDN)[13]

In [13], This study introduces a load balancing mechanism designed for Software-Defined Networking (SDN) in a cloud environment, focusing on an HTTP server handling 400 requests per second, totaling 6 million requests. Due to server overload, additional client requests remain unprocessed. Implementing a load balancing system to reassess these parameters after balancing offers a solution. Instead of relying on a single server, traffic can be distributed across multiple servers. With the integration of an HTTP load balancer, HAProxy effectively manages the incoming traffic, ensuring improved response times and preventing request drops, even when 6 million requests arrive simultaneously. This enhances the availability and reduces the latency of HTTP requests.

Merits- It's crucial to emphasize that traffic from the HTTP server can be split up among several servers rather than just one. Furthermore, it was discovered that both availability and latency had increased following the implementation of

the load balancer mechanism in the HTTP server.
Demerits- There are numerous installation and configuration challenges with the OpenStack cloud. Knowing the OpenStack cloud topology is preferable, as is deciding whether to install on a single node or a distributed system where each machine is in charge of one or more modules. Carefully selecting the Linux distribution to be installed on is also important.

4.14 Learning Automata (LA) [14]

In [14], The researchers introduced an energy-efficient scheduling algorithm (LAEAS) based on Learning Automata (LA) theory for managing independent real-time tasks in a cloud environment. Additionally, they developed a scheduling framework utilizing LA to enhance job allocation efficiency. They compare the efficiency levels of the algorithms using the two measures listed below. The first statistic is the total amount of energy that the virtual machines (VMs) use to run their functions. The second performance metric, known as the success ratio (SR), represents the percentage of tasks completed within their deadline compared to the total number of tasks. By adapting to a dynamic cloud environment, the proposed LAEAS algorithm enables the scheduler to make optimal decisions. This learning-based approach enhances the overall performance metrics of the cloud system.

Merits- The cloud environment's diverse resources, dynamic decision-making, application-specific demands, etc., make it easier to schedule work effectively.
Demerits- Additional planning is required to extend our method to the multi-objective real-time work scheduling algorithm on the cloud.

V. OPEN RESEARCH ISSUES

This research paper provides a thorough analysis of energy-efficient virtual machine allocation. This paper identifies and discusses the primary research gaps in this topic and suggests potential future research directions. The following are some worries regarding open challenges

5.1 Dynamic Workload Management: To optimize energy efficiency without compromising performance, investigate strategies for dynamically adjusting virtual machine (VM) allocations in response to workload fluctuations.
5.2 Resource Consolidation Strategies: Advanced resource consolidation methods, including load balancing algorithms, job scheduling, and virtual machine live migration, are used to balance energy consumption and Quality of Service (QoS) standards.
5.3 Heterogeneous Infrastructure Optimization: Examine methods for optimizing energy efficiency in cloud environments that are heterogeneous and comprise different hardware (such CPUs, GPUs, and FPGAs) and software stacks (like virtualization technologies and containers).
5.4 Energy-Aware Task Scheduling: Investigate energy-conscious task scheduling techniques that assign computing jobs to virtual machines (VMs) with lower energy consumption while accounting for dependencies, deadlines, and resource constraints.
5.5 Security and Privacy Concerns: Consider any vulnerabilities resulting from resource sharing and isolation techniques when analyzing the effects of energy-efficient virtual machine allocation strategies on security and privacy.

VI. CONCLUSION

In conclusion, this investigative research has carefully investigated the critical importance of energy-efficient utilization in virtual machine (VM) allocation within cloud computing environments. In order to achieve energy efficiency in virtual machine allocation, we have examined a variety of research initiatives, methodologies, and challenges. From dynamic workload management to machine learning-based prediction models, researchers have looked into a variety of tactics aimed at optimizing resource utilization while lowering energy consumption Furthermore, the evaluation has highlighted how important it is to consider real-time monitoring and control techniques as well as green data center design concepts when aiming for energy efficiency. Ultimately, by pushing the limits of energy-efficient virtual machine allocation, researchers can contribute to the development of more sustainable and environmentally sensitive cloud computing infrastructures. This will ensure that the benefits of cloud computing are experienced without unduly taxing energy resources. Energy-efficient and secure VM allocation is crucial for sustainable and safe cloud computing. This review highlights various strategies, including dynamic consolidation, AI-driven optimization, secure load balancing, attack mitigation, and green computing techniques. While challenges persist, advancements in AI, federated learning, blockchain, and renewable energy integration offer promising solutions.

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Challenges and Solutions of IoT-Enabled Traffic Surveillance Systems: A Comprehensive Survey

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Abstract: The demand for effective traffic management solutions has increased due to the fast urbanization and rising vehicle density. IoT-enabled traffic surveillance systems have become a viable way to improve road safety, traffic monitoring, and congestion management. Data security, real-time processing constraints, interoperability problems, and high deployment costs are just a few of the major obstacles these systems must overcome. This survey examines various remedies and offers a thorough examination of these issues. We look at important approaches including 5G-enabled communication frameworks, edge computing, blockchain for safe data sharing, and analytics powered by artificial intelligence. We also evaluate new developments and industry best practices that improve the dependability and effectiveness of IoT-based traffic monitoring. Our results emphasize how crucial it is to combine secure communication protocols with sophisticated data processing methods in order to overcome current constraints. The purpose of this study is to help policymakers and researchers create IoT-driven traffic control solutions that are more reliable and scalable.

Keywords: Internet-of-Things, Cloud computing, Fog computing, Smart traffic monitoring

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I. INTRODUCTION

The Internet of Things (IoT) consists of items with distinctive features and connectivity to the Internet. The "things" in the IoT are IoT devices having unique identities and the capacity for remote sensing, actuation, and monitoring. Today, the Internet has almost reached every country in the globe, and its influence on how people live their lives is unimaginable. Applications for IoT extend beyond simply connecting objects to the Internet. IoT makes it possible for these devices to share information while executing essential applications for a typical user's or machine's goals. By enabling sophisticated and networked monitoring systems, the Internet of Things (IoT) has completely changed traffic surveillance. IoT-enabled traffic surveillance systems gather, process, and analyze traffic data in real time using a network of sensors, cameras, and cloud computing. Notwithstanding their benefits, these systems have a number of drawbacks, such as high implementation costs, network latency, data security, and compatibility.

Fig 1. IoT Eco System [IoT&ApplicationsDigitalNotes.pdf(mrcet.com)]

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At the moment, cloud servers handle and store the majority of IoT data. The cloud provides a highly scalable computing infrastructure that can be configured on-demand in a pay-as-you-go fashion. Cut down on the cost of creating the required analytics application. The current data analysis methodology can handle processing huge data volumes kept in centralized cloud storage [7]. The cloud is used to store data. Edge computing, often known as fog computing, is a novel strategy that has been developed in response to the complexities and dynamic nature of the Internet of Things (IoT) [8].

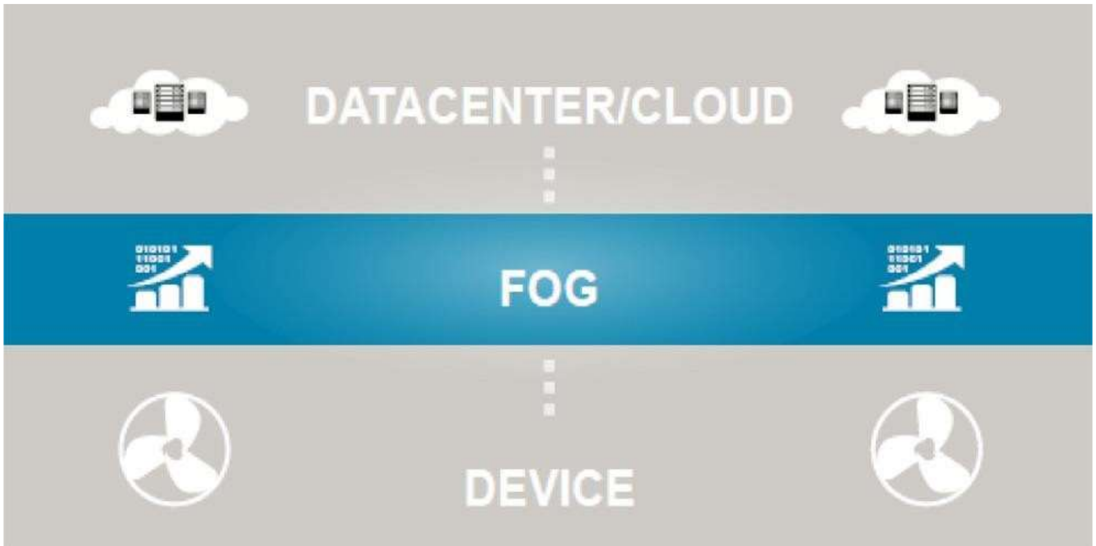

Fig 2. The Network Edge[1]

Previous research has mostly concentrated on particular areas, including data analytics, security risks, or vehicle communication. For instance, prior surveys have looked at the function of edge computing and wireless sensor networks (WSNs) in traffic monitoring, but they frequently don't provide a comprehensive analysis of the various issues these systems confront. Furthermore, although some research has tackled cybersecurity issues in IoT-driven surveillance, it hasn't thoroughly examined solutions designed for various traffic monitoring settings.

This survey article discusses how to build intelligent traffic monitoring systems that accommodate cloud computing and fog computing while addressing the limitations of traditional cloud services for traffic monitoring systems. A vehicle detection sensor is connected to the fog node in this system. Data can be processed locally by fog nodes before being sent to the cloud for further examination. Additionally, comparison studies are conducted to highlight the benefits of fog networks over cloud computing in terms of response time and bandwidth. The development of different techniques depends on the building of automated systems. This study will discuss several traffic monitoring techniques, such as fog computing design for vehicle data classification, cloud computing design for vehicle data classification, traffic signal control, and congestion detection. The rest of this paper is structured as follows: Section II explores different traffic monitoring techniques utilized for vehicle classification. Section III presents a literature review on intelligent traffic monitoring approaches. Finally, Section IV provides the conclusion of the paper.

I. TRAFFIC MONITORING METHODS

Here we will discuss few important methods of traffic monitoring and vehicle classification.

A. Vehicle data classification with cloud computing [1]

A Vehicle in terms of data, traffic data analysis in the cloud to identify vehicle congestion in traffic then Installing sensors on roads to detect traffic at a designated intersection and upload in grew data to the cloud to determine how many vehicles will approach the junction in a specific amount of time. Analyzing the processed data to classify vehicle congestion levels as LOW, MEDIUM, or HIGH, depending on the number of vehicles at the intersection. Depending on a pre-determined threshold, classifying the congestion density as LOW, MED or HIGH. In the event of HIGH congestion, the cloud platform will send a Tweet message (#Traffic Density HIGH-CLOUD) as an alert.

Predicting occurrences like car accidents, breakdowns, road repairs, etc. if the congestion is classified as HIGH.

B. Fog Computing Design for Classifying Vehicle Data[1]

As a component of this process vehicle and traffic data from the cloud Identify the output of data analysis—car congestion in the road firstly, follow the procedure Installing sensors on roadways to monitor traffic at a chosen crossroads, then uploading unprocessed data to the cloud to estimate the number of cars that will approach the in trisection in a given period of time and classifying vehicle congestion as LOW, MED, or HIGH based on the number of cars at the intersection using the processed data after analysis. employing a predetermined threshold to designate the designations for the congestion density HIGH, MEDIUM, or LOW. The cloud platform will tweet an alert with the hash tag #Traffic Density HIGH-Cloud if HIGH congestion is detected. A neighboring fog node (#TrafficDensityHIGH-Fog) receives the raw data and counts the number of vehicles before processing it. Predicting events like car accidents, crashes, and road If the classification of the congestion is HIGH, repairs, etc.

C. Congestion detection[1]

As a Input in this method Traffic data from sensor Initially Check the vehicle Density and vehicle Density is Low then Increment vehicle Count for every incoming vehicle. If vehicle Count is High vehicle Density is #Traffic Density HIGH)High Tweet(Traffic Density HIGH) Display. As a result of traffic data from sensor nodes, we were able to detect congestion.

D. Traffic light control[1]

As a Input in this system Traffic Signals information system. In initial stage check traffic signal, then traffic signal light is red so Vehicle Density is high and same as traffic signal light is green so Vehicle Density is low and we got as a Output is the vehicle concession as a basis for traffic light.

II. LITERATURE SURVEY

The research summary and future scope of this study will be presented in the current section along with various research papers pertaining to smart traffic monitoring and vehicle classification using cloud and fog computing.

Investigating how the fog computing technique might improve the performance of conventional technology for cloud computing is the aim of the current study, which is based on [1] works for traffic monitoring systems. to demonstrate how a fog-based system outperforms conventional cloud-based technologies in terms of bandwidth and response time for applications that are sensitive to latency. Preliminary experiments are conducted. A traffic monitoring system is looked at as a case study. It is found that the response time and bandwidth of the fog network are around 258 times faster than those of the cloud network, while the bandwidth of the cloud network is almost 5 times smaller.

In paper [2] researchers developed To traffic control performance Adaptive traffic system include multiple technologies such as loop detector, camera detector, infrared, radar, etc. To further improve traffic control performance, adaptive traffic system includes loop detector, camera detection includes multiple technologies such as vessels, infrared, radar, etc.

The drone serves as an empty camera sensor to monitor the area of interest in our experimental surveillance system described in paper [3]. The ground controller receives the raw video stream, which is then shown on the security screen. When an application user spots a suspicious vehicle, the target is blocked and a video frame is sent to the fog node for tracking and speed calculation, according to a case study on intelligent traffic monitoring. The results and processed patches are promptly transmitted back to the ground control station after the speed has been determined. taking into account the HD video frame's dimensions.

In the article [4] Data collection, cleaning, clustering, time series comparison, data retrieval for visualization, chart and report creation, and mobile client notifications are among the system's capabilities. The system employs a special agent for remote photo and video fixation in order to gather statistics and aid in decision-making. complicated and automated data upload. The agent gathers and downloads various sensor data pertaining to traffic parameters, as well as images and frames from the video stream.

The article [5] describes a fog machine in which the number of images sent represents the total amount of time spent monitoring. Since the video was made with a frame size of 20 frames per second, I assumed that there was a violation every five minutes (the worst case scenario). After 100 minutes of monitoring with 20 moving violations, the camera records a total of 120,000 frames of the vehicle in front.

In the article [6] Many of the features of cloud computing, from which fog computing is derived, are retained. Users can still keep their packages and data offsite, and they can now pay for more than just offsite storage—they can also get cloud enhancements and protection for their data, including the use of fog computing mode.

In the destiny work [7], we are able to layout simulations on actual town maps and acquire greater actual site visitors information to provide a automobile generation model (taking rush hour into consideration). Also, we are able to uppload well-informed smart vehicles (dynamically making plans its course from street information) with the aid of using smart simulators and algorithms to perceive the benefits of our framework

TABLE I:
OVERALL SUMMARY OF LITERATURE SURVEY

Sr. No.	Paper Title	Author contribution	Result	Future Scope
1.	Internet of Things-based Fog and Cloud Computing Technology for Smart Traffic Monitoring [1].	A cloud and fog computing architecture is proposed to improve complicated surveillance systems in terms of reaction network capacity and time.	As an example, let's look at a traffic monitoring system. Even though the fog network's reaction time and bandwidth are 258 times quicker, the cloud's bandwidth is just roughly a sixth of the fog's.	Create a car generation model, we will create simulations using real city maps and more real traffic data in the future (taking into account the attacker). To determine the benefits of our framework, we will also be well-informed about intelligent vehicles (dynamic route planning based on road information).
2.	Phase Timing Optimization for Smart Traffic Control Based on Fog Computing.[2].	Proposing a fog- based intelligent traffic signal system Traffic data is stored in a control architecture. Mostly from Edges rather than the middle of distant clouds, collected by different sensors..	In order to further enhance traffic management effectiveness, adaptive transportation systems use a variety of technologies, including B. Loop detector, cameras, infrared, and radar	In future work, we plan to design and implement software units that can support adaptable updates and upgrades to adapt to new control policies.
4.	Intelligent monitoring system for smart road environment [4]	Photo-video fixed remote inquiries Complex and automated data uploads are handled by a dedicated agent in the system Photos and frames from the video stream, and also sensor data pertaining to traffic factors.	Network results showed acceptable errors with an averageof13% prediction. These variations in the number of incidents and their influence on temperature regimes might be predicted using this model.	In future we have to try to implement web cam on road so this device give advance information about road traffic.

5.	Smart traffic control: Identifying driving-violations using fog devices with vehicular cameras in smart cities [5]	Each time the machine is activated, a certain number of photos are communicated. He assumed that the video has been created at a framerateof20fpsandthat a violation occurred every five minutes.	Given the size and length of the video, the system efficiency statistics show a good Throughput and a fast processing time	At the beginning, a lane detection algorithm employing the Hough transform and a vehicle detection mechanism utilizing SSD
6.	Smart Fog Based Workflow for Traffic Control Networks [6]	A traffic management system based on fog-based intelligence Because of the computational paradigm and the dispersion gain method.	Optimization is the key. A network of interconnected automobiles and strategies for their reinforcement Leading developer of next-generation smart transportation technologies.	Design the simulation the more real traffic data on a real city map to create a generation vehicle

TABLE II:

COMPARISON TABLE SUMMARIZING KEY APPROACHES FOR IOT-ENABLED TRAFFIC SURVEILLANCE SYSTEMS:

Approach	**Accuracy**	**Scalability**	**Cost**	**Response Time**	**Real-World Applicability**
Computer Vision-Based	High	Moderate	High	Fast	Widely Used
AI/ML-Based Analytics	Very High	High	High	Fast	Emerging
Sensor-Based (e.g., RFID, LIDAR)	Moderate	High	High	Moderate	Industry Adoption
Crowdsourced Data (e.g., GPS, Mobile Apps)	Moderate	Very High	Low	Fast	Popular
Hybrid (AI + Sensors + Cloud)	Very High	Very High	High	Fast	Future Trend

IV. OPEN RESEARCH CHALLENGES

IoT-enabled traffic surveillance systems have advanced, however there are still a number of unresolved research issues. The enormous volume of data produced by sensors, cameras, and connected cars necessitates effective processing, storage, and real-time analysis, making data management and scalability a major challenge. Because IoT devices are vulnerable to cyber attacks, unauthorized access, and data breaches, ensuring data privacy and security is also a crucial concern. Furthermore, as different IoT devices, communication protocols, and platforms must work together seamlessly to provide efficient surveillance, interoperability and standardization present challenges. In order to ensure accurate vehicle and pedestrian detection, traffic monitoring systems must handle a variety of environmental conditions, such as poor lighting, occlusions, and changing weather conditions. Additionally, the cost and upkeep of IoT infrastructure can be a barrier to widespread deployment, especially in developing regions. Finally, ethical and legal concerns regarding surveillance, data ownership, and citizen privacy must be addressed in order to promote public trust and regulatory compliance. The deployment of edge and cloud computing for real-time decision-making also requires further optimization to balance latency, energy consumption, and computational efficiency. Finally, enhancing the resilience of IoT-based traffic systems against failures, cyberattacks, and harsh weather remains a crucial research focus. Addressing these difficulties will enable the creation of more robust, efficient, and secure IoT-enabled traffic surveillance systems for smart cities.

Here’s a critical analysis of the surveyed works on IoT-enabled traffic surveillance systems:

Strengths of Existing Approaches

1. **Enhanced Accuracy through AI & ML**
    - Advanced deep learning techniques improve object detection, classification, and anomaly detection in traffic monitoring.
    - Real-time decision-making is possible with edge computing integration.
2. **Scalability and Data Collection**
    - IoT devices (sensors, cameras, and GPS) enable large-scale data collection.
    - Cloud-based architectures support real-time analytics on massive datasets.
3. **Automation and Predictive Analytics**
    - AI-driven predictive analytics help in congestion prediction, accident prevention, and optimized traffic signal control.
    - Automation reduces human intervention, increasing system efficiency.

Gaps and Limitations

1. **Data Privacy and Security Concerns**
    - IoT devices are vulnerable to cyberattacks, leading to potential data breaches.
    - Ensuring secure data transmission and storage remains a major challenge.
2. **High Deployment and Maintenance Costs**
    - Implementing high-resolution cameras, LIDAR, and AI-driven systems is expensive.
    - Maintenance and system integration costs limit adoption in developing regions.
3. **Limited Real-World Validation**
    - Many studies rely on simulations rather than real-world implementations.
    - Scalability challenges emerge when tested in uncontrolled environments.
4. **Latency and Response Time Issues**
    - Processing large volumes of real-time traffic data can lead to delays.
    - Edge computing solutions help but require significant infrastructure investment.
5. **Heterogeneous Data Sources and Standardization Issues**
    - Integrating data from different IoT devices, mobile apps, and traditional surveillance systems lacks standard protocols.
    - Data fusion techniques are needed to handle multi-source inconsistencies.

V. CONCLUSION

Through the use of cutting-edge technology like artificial intelligence (AI), computer vision, sensors, and cloud computing, IoT-enabled traffic surveillance systems have greatly enhanced traffic management. There are still a number of obstacles to overcome despite their benefits in increasing traffic monitoring, lowering congestion, and boosting road safety. These include the requirement for real-time processing, network scalability, significant implementation costs, and data privacy issues. To lessen these difficulties, a number of alternatives have been put forth, including edge computing, blockchain for security, and hybrid AI models. A comparative study of various methods reveals the compromises between scalability, cost, accuracy, and practicality. All things considered, IoT-driven traffic surveillance is still developing and promises to provide more intelligent and effective urban mobility solutions.

VI. FUTURE SCOPE

The integration of cutting-edge technologies to solve current issues and improve efficiency is key to the future of IoT-enabled traffic surveillance systems. Optimizing edge computing to allow for real-time traffic monitoring with lower latency and less dependence on cloud infrastructure is a crucial field of research. Furthermore, maintaining data security and privacy is still a major challenge, requiring the creation of strong encryption methods, blockchain-based authentication, and AI models that protect privacy like federated learning. High-speed data transmission is made possible by the quick development of 5G and next-generation networks, which enhances the scalability and reactivity of IoT-based surveillance.

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Comprehensive Analysis of Efficient Load Balancing Algorithms in Cloud Computing

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Abstract: In the distributed computing world, cloud computing has recently become a buzzword. Many people think that cloud computing will revolutionize the IT sector. It's provides us the means by which we can access the application as utilize our internet. Moreover, refers the manipulating configuring and accessing the application online. One paradigm for providing network access to a shared pool of reconfigurable computing resources that is universal, easy, and on-demand is cloud computing. (such as servers, networks, storage, apps, and services) that require no maintenance labor or communication with service providers and may be quickly provided and released. The pressure on the cloud is growing daily because almost every industry wants to use these services to lower infrastructure and maintenance costs. One of the main problems cloud computing is now facing is load balancing. This paper will discuss about balancing the load in cloud environment, need of load balancing, existing literature on load balancing algorithms, and widely used performance metrics for load sharing and a thorough examination of the algorithms found in the literature.

Keywords: Cloud Computing, Load Balancing, Static Load Balancing Algorithms.

I. INTRODUCTION

The technology that is becoming more and more popular these days is cloud computing. Since technology is advancing daily, it is truly impossible for a business to compete without maintaining its resources and technological capabilities. The adoption of these technologies requires significant infrastructure investment, which is not affordable for all businesses. These issues have been resolved by cloud computing, which offers pay-per-use, on-demand services that are accessible online. The flexibility and ease of use it offers for on-demand hardware or software services is the main reason why it is currently embraced by the majority of industries, academic institutions, and corporations. It can make cost-effective use of any type of resource, whether local or remotely accessible.

Since the greater part of businesses, today, wish to utilize these administrations to decrease foundation and support cost, the heap is builds step by step accordingly making load adjusting a difficult and significant territory of study for the researchers. The objective of this paper is to give a concise survey of well known burden adjusting procedures in distributed computing. The paper centers around need of burden adjusting and kind s of burden adjusting methods in area ii which followed by Literature study of existing algorithm proposed by different analysts with Analysis of calculations based on different boundaries called as execution measurements in segment iii and iv separately. At last, area v include with finish of the work.

http://doi.org/10.63766/spujstmr.24.000043

II. DIFFERENT LOAD BALANCING ALGORITHMS

The implementation of the algorithm necessitates careful planning and process analysis because cloud computing is a vast collection of resources that must be managed properly. Load balancing algorithms can be categorized into different types, namely: Static, Dynamic, Centralized, Distributed and Hierarchical based on the type of algorithm used.

A. Static Load Balancing:

In static calculation the traffic is isolated uniformly among the workers. This calculation requires an earlier information on frame work assets the presentation of the processors is resolved toward the start of the execution, consequently the choice of moving of the heap doesn't rely upon the present status of framework.

Merit: Static load balancing is simple to implement, as tasks are pre-assigned, reducing runtime complexity and system overhead. It ensures fast execution, efficient resource use in homogeneous systems, and deterministic performance with predictable workload distribution. Without real-time monitoring, it also lowers computational overhead, making it energy-efficient for fixed workloads.
Demerit: Static load balancing lacks adaptability, making it inefficient for changing workloads or system failures. It cannot redistribute tasks dynamically, leading to potential overloading or underutilization, especially in heterogeneous environments. Its rigidity may cause bottlenecks and inefficiencies if the initial task allocation is suboptimal.

B. Dynamic Load Balancing:

These calculations are suitable for situation where heterogeneous assets are available. In this no earlier information is required. The provisioning is finished by present status of framework. The prerequisites may change at the show time to the clients. These calculations are hard to carry out however exceptionally reasonable for cloud climate.

Merit: Dynamic load balancing optimizes resource utilization by continuously adjusting workloads based on real-time system conditions. It enhances performance, prevents bottlenecks, and ensures efficient task distribution across heterogeneous environments. This adaptability improves fault tolerance, reduces response time, and maximizes system reliability, making it ideal for unpredictable or fluctuating workloads.
Demerit: Dynamic load balancing increases system overhead due to continuous monitoring and real-time decision-making. It adds complexity to implementation and may cause delays in task allocation. In high-load scenarios, frequent adjustments can lead to instability. Additionally, it requires efficient communication between nodes, which can consume extra network and computational resources.

C. Incorporated Load Balancing

In this situation the designation and de-assignment of assets on the organization is finished by a focal hub, for the most part called as organizer. The facilitator stores all the knowledge about the organization and applies calculation as indicated by the necessity.

Merit: Incorporated load balancing enhances efficiency by combining static and dynamic approaches, leveraging predictability while adapting to workload fluctuations. It optimizes resource utilization, improves fault tolerance, and reduces response time. This hybrid method balances stability and flexibility, ensuring smooth performance in both predictable and dynamic environments while minimizing overhead and bottlenecks.
Demerit: Incorporated load balancing increases system complexity by combining static and dynamic strategies, requiring sophisticated algorithms for effective implementation. It may introduce higher computational overhead due to real-time monitoring and decision-making. Additionally, improper integration can lead to inefficiencies, increased latency, or resource contention, reducing overall system performance in certain scenarios.

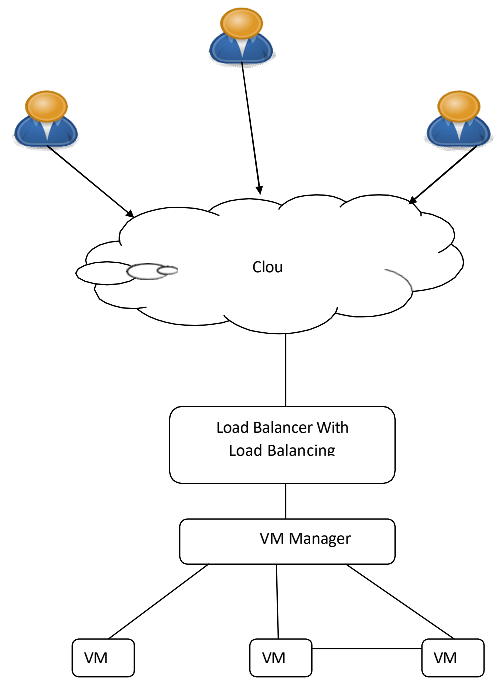

Fig-l Balancing the load in cloud computing

D. Circulated Load Balancing

In this calculations no single hub is able for load dissemination. Various facilitators in various paces are available to screen the organization and answerable for load adjusting. Each hub in every space keeps up the neighborhood information base and pass something similartotheorganizerwhichmakesworldwideinformationbasetoenvision the circumstance of the organization.

Merit: Circulated load balancing evenly distributes workloads across multiple resources in a cyclic manner, ensuring fair task allocation. It is simple to implement, reduces the risk of overloading any single node, and enhances system stability. This method works well in homogeneous environments, providing efficient resource utilization with minimal computational overhead.

Demerit: Circulated load balancing may lead to inefficiencies in heterogeneous environments where nodes have varying processing capabilities, as tasks are assigned without considering resource capacity. It lacks adaptability to dynamic workload changes, potentially causing bottlenecks. Additionally, it does not account for system failures, leading to possible performance degradation or task delays.

E. Various leveled Load Balancing

In this calculations cloud network is isolated in levels and each level takes an interest in load adjusting. These heap adjusting methods for the most part work in ace slave mode. The method imagines the cloud network as tree structure.

Merit: Various leveled load balancing optimizes resource allocation by considering different hierarchy levels, ensuring efficient workload distribution across diverse system architectures. It enhances scalability, improves fault tolerance, and adapts to dynamic workload changes. This approach balances efficiency and flexibility, reducing bottlenecks and improving overall system performance, especially in large-scale or multi-tier environments.

Demerit: Various leveled load balancing increases system complexity due to its hierarchical structure, requiring sophisticated algorithms for coordination. It introduces higher computational and communication overhead, potentially slowing down task distribution. Additionally, improper configuration or imbalance between levels can lead to inefficiencies, resource contention, or delays in processing, impacting overall system performance.

F. Static Round Robin Load Balancing Algorithm

In this calculation, fixed quantum time is given to the work. It designates occupations to all hubs in a roundabout style. Processors are allotted in a roundabout request and subsequently there is no starvation. It's gives quicker reaction on account of equivalent responsibility conveyance among measures.

Merit: Simple to implement and ensures fair workload distribution by assigning tasks cyclically. It reduces the risk of overloading a single node and works well in homogeneous environments. With minimal overhead and no need for real-time monitoring, it offers fast and efficient task allocation.

Demerit: It does not consider node capacity, leading to inefficiencies in heterogeneous environments where some nodes may be overloaded while others remain underutilized. It lacks adaptability to workload variations and system failures, potentially causing bottlenecks. Additionally, task switching may introduce unnecessary overhead.

G. Weighted Round-Robin Load Balancing Algorithm

In this algorithm, it created to improve the basic issues with cooperative calculation . In weighted cooperative calculation, every worker is appointed a weight and as indicated by the estimations of the loads, occupations are conveyed. Processors with more prominent capacities are relegated a bigger worth Consequently the most elevated weighted workers will get more undertakings. In a circumstance where all loads become equivalent, workers will get adjusted traffic.

Merit: The Weighted Round Robin load balancing algorithm improves efficiency by assigning tasks based on server capacity, ensuring better resource utilization in heterogeneous environments. It prevents overloading weaker nodes, enhances performance, and reduces response time. This method maintains fairness while adapting to varying processing power, leading to improved load distribution and system stability.

Demerit: It assumes static weight assignments, which may not reflect real-time system conditions, leading to inefficiencies. It does not account for sudden workload spikes or node failures, potentially overloading some servers. Additionally, improper weight configuration can cause imbalanced task distribution.

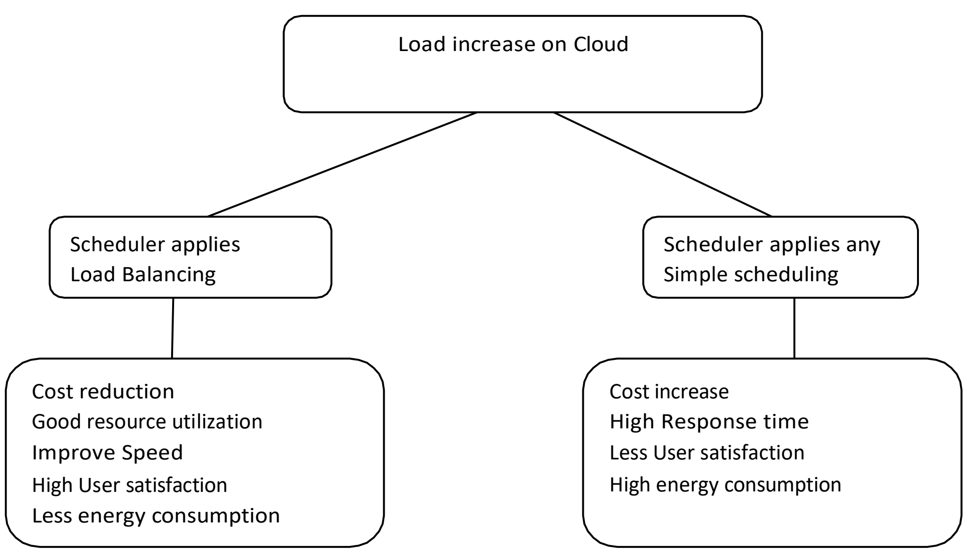

Fig-2 Benefits of load balancing

III.LITERATURE SURVEY

T. Dillon et al. [1] This study looked at the challenges and problems associated with cloud processing. We explained the relationships between Grid processing, Service-Oriented Computing, and Cloud registration. We broke down a couple of difficulties in transit towards receiving Cloud processing. The interoperability issue was featured and various arrangements are examined from there on for various cloud administration organization models.

P. Kumar et al.[2]load-adjusting techniques are energy saving, and errand load the executives, which requires growing new calculations. gets important to dissect recently evolved and recent load-adjusting procedures from various classifications on test systems dependent on different load balancing metrics to check the viability of these calculations before sending in the actual cloud climate.

A. Hota et al. [3]Cloud processing framework has generally been received by the business and scholarly. Be that as it may, there are numerous issues which exist in this climate like burden adjusting, In this paper, different burden adjusting calculations have been given their benefit and drawback. The review paper gives plentiful extension to scientists to create proficient burden adjusting calculations for cloud climate.

S. Shaw etal. [4]In this paper, we studied various calculations for load adjusting in Cloud Computing. Burden adjusting has two implication first, it puts countless simultaneous gets to or information traffic to various hubs individually to diminish the time clients holding up for response second, it put the estimation from a solitary hefty burden to the different hubs to improve the asset use of every hub.

N. Shah et al. [5] Load adjusting is vital in distributed computing if proficient and most extreme use of assets should be accomplished. In this paper, we have talked about the current static burden adjusting plans accessible for distributed computing. We have likewise distinguished the holes in current static burden adjusting calculations.

P.Samaletal.[6]The heap appropriation issue on different hubs of a conveyed framework is tackled in the current work to improve both asset use and occupation reaction time by examining the variations of RR calculation. The over-burdening and under loading circumstances are evaded. Subsequently, load adjusting guarantees that all the processor in the framework or each hub in the organization does roughly the equivalent measure of work whenever you want. When compared to other computations, the suggested calculation demonstrates a faster reaction time.

S.Pateletal.[7]Cloud Computing alongside research difficulties in load adjusting. It additionally center around benefits and faults of the distributed computing. A close examination of the aforementioned computations in distributed computing concerning steadiness, asset usage, static or dynamicity, helpfulness or non-helpfulness, and cycle relocation follows a significant push on the study of burden adjusting calculation.

S. Patidar et al.[8] In order to distribute the vocations into the most suitable virtual machines (VMs), the enhanced weighted cooperative computation in this paper takes into account the task duration of each requested occupation as well as the limitations of each VM.

D. Chitra Devi et al.[9] In this paper ,work had considered the general fruition time of all the taking an interest occupations in various calculations. All things being equal, in the future improvements, the consummation season of each job can be thought about in the diverse planning and burden balancing algorithms. The calculations can be tweaked further to achieve the better predictable outcomes on all the different perspectives. Essentially, the examination results ought to betaken for the distinctive occupation appearance designs on all the three different booking and burden adjusting calculations.

H. Shoja et al.[10] Load adjusting is the primary difficulties in distributed computing. It's needed to disseminate the powerful nearby responsibility equally across every one of the hubs to accomplish a high user satisfaction and asset usage proportion by ensuring that each processing asset is dispersed effectively and decently.

I .Saiduet al.[11]we propose another parcel booking calculation, load-mindful weighted cooperative effort (LAWRR), for 802.16 organizations in the downlink heading to enhance the productivity of WRR.

M.Kauretal.[12]In these paper , it has been reviewed that heap adjusting is a significant worry in distributed computing. In the essential intension of burden adjusting is to fulfill the client while conveying load among a few hubs. In addition, the legitimate use of assets with improved execution and utilized static and dynamic burden adjusting calculations.

Sajjan R.S et al. [13] In this paper, Load adjusting is quite possibly the main issue of distributed computingIt is a device that distributes accountability equally among all of the cloud's hubs. We are able to achieve high asset utilization and client fulfillment. These will enhance the framework's overall appearance and usefulness.

S. Mayur et al. [14] In present, Load adjusting is the significant difficulties in the distributed computing. In this paper we examines numerous as of now investigated load adjusting techniques, which depends essentially on overhead decrease, framework execution improvement, improved asset utilizes client reaction time and throughput advancement with cooperative effort and weighted cooperative calculation.

IV. PERFORMANCE METRICS AND ANALYSIS OF VARIOUS ALGORITHMS

- **Makespan:** Total length of the time table when all positions are done. This boundary ought to be least, since it the less time calculation will take for fulfillment great will be execution.
- **Throughput:** It is the measure of work to be done in the given measure of time.
- **Response time:** It is the measure of time used to begin satisfying the interest of the client in the wake of enrolling the solicitation.
- **Resource Utilization:** how much assets are used in effective way.
- **Overhead:** measure the overhead needed for correspondence between to hubs because of development of errands.
- **Fault tolerance:** It is the capacity of the heap adjusting calculation that permits framework to work in some disappointment state of the framework.
- **Scalability:** It is simply the capacity of the calculation to scale itself as per required conditions.
- **Performance:** It is the general check of the calculations working by thinking about exactness, cost and speed.
- **Waiting time:** A period taken by an action in the line to sitting active for finding the opportunity for execution in the wake of getting asset or machine.

TABLE-I:
TABULAR FORMATE OF LITERATURE VIEW

Paper title/ Journal	**Author/year**	**Overall domain**	**Author contribution**	**Results**	**Further Improvements**
Issues and Challenges Of load Balancing Techniques In cloud Computing: A survey[2], ACM Computing Surveys,	Pawan Kumar And Rakesh Kumar,2019	Load Balancing Technique S.	This Survey Presents State-Of-The-Review Of Issues And Challenges Associated With Existing Load-Balancing Techniques For Researchers To Develop More	This Study Will Be Helpful For Researchers To Identify Research Problems Working In The Load Balancing Field And Will Provide A Summary Of Available Load-Balancing	Developers And Researchers To Design And Implement A Suitable Load Balancer For Parallel And Distributed Cloud Environments.

Vol.51,No.6, Article 120. Publication Date: February 2019.			Effective Algorithms.	Techniques.	
Survey of Different Load Balancing Approach-Based Algorithms In cloud Computing: A Comprehensive review[3], Springer2019	Arunima Hot A, Subasish Mo Hapatraand Subhadarshin i Mohanty, 2019	Load Balancing Techniques	This Survey Paper Presents A Comprehensive And Comparative Study Of Various Load Balancing Algorithms.	It Increases The Efficiency Of The System By Equally Distributing The Work Load Among Competing Processes.	The Study Also Portrays The Merits And Demerit So Fall The State-Of-The-Art-Schemes Which May Prompt The Researchers For Further Improvement In Load balancing Algorithms.
A survey on Scheduling and load Balancing Techniques In cloud Computing Environment [4],20145th International Conference on computer and Communication Technology (ICCCT)	Subhadra Boseshaw, Dr.A.K. Singh,2014	Scheduling And Load Balancing Technique	In This Paper, We Have Discussed Different Algorithms Proposed To Resolve The Issue Of Load Balancing And Task Scheduling In Cloud Computing.	To Balance The Load In Cloud The Resources And Workloads Must Be Scheduled In An Efficient Manner.	More Efficient Load Balancing Techniques Can Be Developed In Future.
Static load Balancing Algorithms In cloud Computing: Challenges &Solutions [5], International Journal Of scientific & Technology Research Volume4, Issue10, October2015	Nadeem Shah, Mohammed Farik,2015	Static Load Balancing Algorithms	The Aim Of This Review Paper Is To Understand The Current Challenges In Cloud Computing, Primarily In Cloud Load Balancing Using Static Algorithms.	The Aim Of This Review Paper Is To Understand The Current Challenges In Cloud Computing, Primarily In Cloud Load Balancing Using Static Algorithms.	Improve More Efficient Static Cloud Load Balancing In The Future.

Analysis of Variants in Round robin Algorithms For load Balancing In cloud Computing [6], International journal Of computer Science and Information Technologies ,Vol.4(3), 2013,416-419	Pooja Samal, Pranati Mishra,2013	load balancing in Cloud Computing	Improve resource utilization and job response time by analyzing the variants of RR algorithm.	This algorithm, which divides the traffic qually, is announced as round robin algorithm.	Improve the performance by balancing the load among various resources.
Implementation of load Balancing In cloud Computing Thorough Round robin &Priority Using Cloudsim[7], International Journal For rapid Research in Engineering Technology &Applied Science vol 3, Issue11 November 2017.	Shweta Patel, Prof. Mayank Bhatt,2017	Load balancing In Cloud Computing	Round Robin algorithm in different time slices to individual processes depending on their priorities.	Good load balancing makes cloud computing more efficient and improves user satisfaction.	The load balancing strategy to improve the efficiency in the cloud environment.
Load Balancing In cloud Computing Using Modified Round robin Algorithm [8], International Journal Of scientific Research& Engineering Trends Volume6, Issue4,July-Aug-2020,	Srushti Patidar , Assistant Prof. Amit Saraf, 2020	Load Balancing In Cloud Computing	Weighted round robin calculation considers the capacities of each VM and the errand length of each asked for occupation to allot the employments in to the most suitable VMs.	Basic to build up a calculation which can enhance the framework execution by adjusting the work stack among virtual machines.	Implement Weighted round Robin

Issn(Online): 2395-566x					
Load Balancing In cloud Computing Environment Using Improved Weighted Round robin Algorithm For Non preemptive Dependent Tasks[9], Ramanujam Computing Centre, Anna University, Chennai600 025,India, Received29 November 2015; Accepted21 December 2015.	D. Chitra Deviand V. Rhymend Ut Hariaraj, 2015	Load Balancing in Cloud Computing	Weighted round robin algorithm considers the capabilities of each VM and the task length of each requested job to assign the jobs into the most appropriate VMs.	Weighted round robin algorithm is most suitable to the heterogeneous/homogenous jobs with heterogeneous resources(VMs) compared to the other round robin and weighted round robin algorithms.	Improved weighted round robin algorithm.

TABLE-II:
TABULAR FORMAT OF PROPOSED TECHNIQUE, ADVANTAGES AND DISADVANTAGES

Paper Title/ Journal	Author/year	Proposed Technique	Advantages	Disadvantages
Issues And Challenges Of Load Balancing Techniques In Cloud computing: A Survey[2], ACM Computing Surveys, Vol. 51, No. 6, Article 120. Publication Date: February 2019.	Pawan Kumar and Rakesh Kumar, 2019	Distributed algorithm; Concurrent algorithm.	All the nodes in the distributed system are connected to each other, so node can easily share load.	It is difficult to provide security in distributed Systems.
Survey Of Different load	Arunima Hota, Subasish Moha	Round Robin algorithm	It works well with no of processes	Some of the nodes are heavily loaded and

Balancing Approach-Based Algorithms In Cloud computing A comprehensive Review [3], Springer2019	patra and Subhadarshini Mohanty , 2019			Some of the mare under loaded. Such situation can lead to poor performance of the system
A Survey On Scheduling And Load Balancing Techniques In Cloud computing Environment [4], 2014 5th International Conference On Computer and Communication Technology (ICCT)	Subhadra Bose Shaw, Dr. A.K.Singh,2014	Task Scheduling Algorithm	Manage all the system performance and Qos.	These algorithms cannot adapt to load changes during run-time.
Static Load Balancing Algorithms In Cloud computing: Challenges & Solutions [5], International Journal Of Scientific &Technology Research volume 4, Issue 10, October2015.	Nadeem Shah, Mohammed Farik ,2015	Round-Robin algorithm.	Faster task completion	Lost some process
Analysis Of Variants In Round Robin Algorithms for Load Balancing In Cloud Computing [6], International Journal Of Computer science And Information Technologies, Vol.4(3) ,2013,416- 419	Pooja Samal, Pranati Mishra,2013	Round Robin (RR) algorithms.	A better distribution of the communication traffic so that the website availability is conclusively settled.	Long time system responses

Implementation Of Load Balancing In Cloud computing Thorough round Robin & Priority Using Cloudsim[7], International Journal For Rapid research in Engineering Technology & Applied Science Vol 3 Issue 11 November2017.	Shweta Patel, Prof. Mayank Bhatt, 2017	Round Robin Algorithm	Round robin algorithm can be via far the easiest algorithms how to help distribute populate among nodes. Because of this reason it is frequently the first Preference when implementing a easy scheduler.	Implementing a simple round robin architecture in cloud computing by introducing a concept of assigning different time slices to individual processes depending on their are priorities.
Load Balancing In Cloud Computing Using Modified Round Robin Algorithm [8], International Journal Of Scientific Research &Engineering Trends Volume 6, Issue4, July-Aug-2020, ISSN(Online): 2395-566x	Srushti Patidar, Assistant Prof. Amit Saraf, 2020	Round Robin Algorithm	Easy to use and implement	Poor framework execution and looking after security
Load Balancing In Cloud Computing Environment Using Improved Weighted Round Robin Algorithm For Non preemptive Dependent Tasks [9], Ramanujam Computing Centre, Anna University, Chennai 600 025, India, Received29 November 2015; Accepted21 December2015.	D. Chitra Deviand V. Rhymend Utha riaraj , 2015	Weighted Round Robin.	The weighted round robin considers the resource capabilities of the VMs and assigns higher number of tasks to the higher capacity VMs based on the weightage given to each of the VMs	Higher response time

V. CONCLUSION

Today, load adjusting is the one of the greatest issue in distributed computing. The heap must be conveyed reasonably among every one of the hubs. The primary advantages of Load adjusting are ideal usage of assets and increment throughput with lesser energy utilization at last bringing about green registering, static calculation is created by joining the highlights of the weighted round-robin calculation load adjusting calculation to connect the holes of both.

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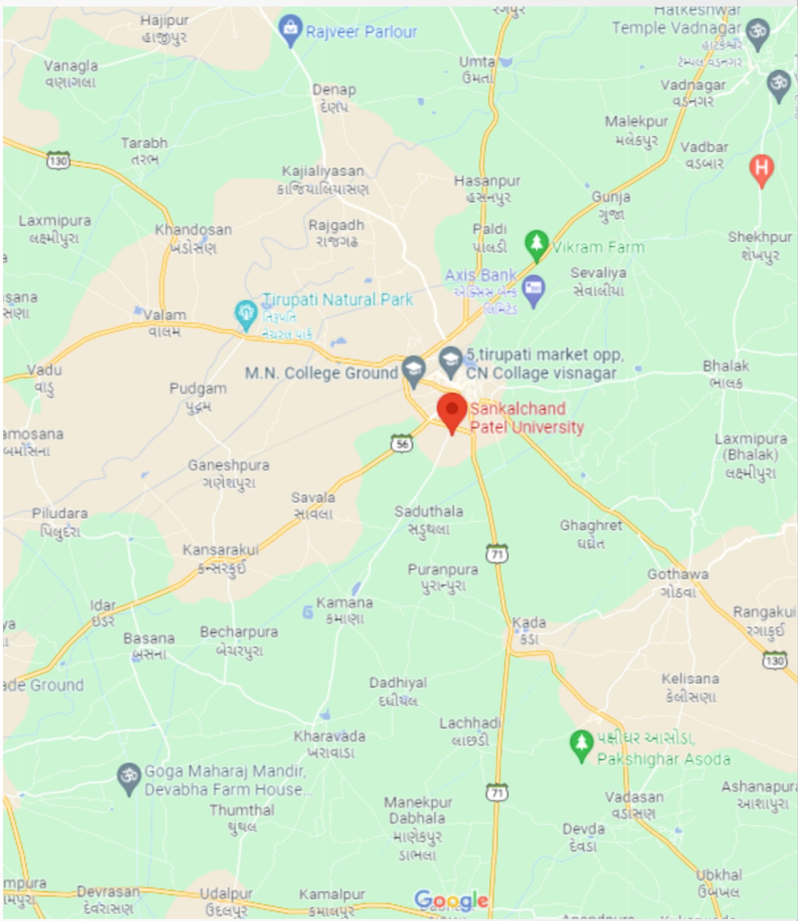

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