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Editorial

Innovative Pathways for a Sustainable Future: Turning new ideas into real actions is one of the biggest challenges in achieving sustainability today. Many innovative ideas are being developed in science and technology, but they become truly valuable only when they are put into practice. Sustainability is no longer just a concept; it requires practical and workable solutions to solve major global problems like climate change, shortage of resources, and environmental damage. To make this happen, we need a clear and inclusive approach that connects research with real-world application.

To solve sustainability challenges, knowledge from different fields must come together. Areas such as engineering, environmental science, economics, social sciences, and public policy all play an important role. These challenges cannot be solved by working alone; they require teamwork and cooperation. Solutions must be technically possible, economically affordable, environmentally safe, and socially acceptable. For example, renewable energy projects should combine technology with supportive government policies and active involvement from communities. This helps ensure that solutions are effective and can be used in different places and conditions.

Institutions, industries, and governments also play a key role in this process. Educational institutions generate ideas and train skilled people, while industries help turn these ideas into real products and services. Governments create rules and policies that support safe and responsible innovation. When all these groups work together, they create a strong system where ideas are developed, tested, improved, and implemented. Encouraging partnerships between public and private sectors can speed up this progress.

In the end, sustainability is everyone's responsibility. It goes beyond fields of study and national boundaries. Success depends on continuous cooperation, sharing of knowledge, and adapting to new challenges. As the world changes, our solutions must also evolve. True progress is achieved not just by creating new ideas, but by successfully applying them. This is how we can build a better, stronger, and more sustainable future for the coming generations.

Vision becomes reality only when innovation is guided by collaboration and sustained by purposeful implementation

New Delhi
March 2026

Editor-in-Chief

Sharnbasva University

Kalaburagi, Karnataka, India

(A Private university enacted by Govt. of Karnataka as “Sharnbasva University Act 2012”

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Investigation of the Tribological Properties of Al 7079 Alloy Reinforced with Agricultural Waste Particles

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ABSTRACT

In recent years, composite materials have gained popularity over traditional monolithic materials due to the growing demand for high-quality, high-performance materials. Aluminium-based metal matrix composites (MMCs) are particularly prominent in industries such as automotive and aerospace, owing to their superior strength-to-weight ratio, enhanced resistance to corrosion and wear, and excellent performance at elevated temperatures. The stir casting technique has proven to be the most efficient method for fabricating these metal composites when reinforced with materials like SiC, Al₂O₃, graphite, and coconut shell ash. This study investigates the tribological properties of Al 7079 alloy reinforced with graphite and coconut shell ash particles at specific weight percentages. The results of the wear tests indicate that the inclusion of coconut shell ash helps reduce material loss in the composite, a trend also observed with graphite reinforcement.

KEYWORDS : *Tribological, Characteristics of Al 7079, Alloy reinforced, Agricultural waste particles.*

INTRODUCTION

Over the past decade, metal matrix composites (MMCs), often reinforced with ceramic particles, have gained popularity due to their ability to meet the demands of applications requiring both high wear resistance and light weight. Aluminium alloys are widely used in various industries because of their light weight and reasonable strength. However, despite their advantages, aluminium alloys exhibit poor tribological properties. Their primary limitation lies in their inadequate wear resistance, unpredictable behavior in lubricated environments,

and difficulty in maintaining a consistent lubricating layer on the sliding surface. As a result, researchers have increasingly turned to aluminium-based composites, reinforced with single or multiple particles, for critical applications. Hybrid composites, which combine different reinforcements, are particularly favored for high-performance materials due to their enhanced tensile strength, modulus, compressive strength, and impact strength.

In recent years, there has been a focus on utilizing agricultural waste materials, such as coconut shells, rice husks, apricot, and nutshells in the form of ash, to develop metal matrix composites. The high carbon content in these materials contributes to increased strength while maintaining a lower weight. Bledzki et al. conducted a study using barley husk and coconut shell particles to create polymer composites, concluding that the addition of these agricultural wastes enhanced the tensile strength by up to 80% and improved both impact strength and elongation properties. Similarly, Alaneme et al. studied the corrosion and wear behavior of aluminium composites reinforced with rice husk ash and alumina, finding that the corrosion resistance of aluminium alloy reinforced with alumina alone was significantly higher than that with the addition of rice husk ash. They attributed this to the increased number of reinforcing particles at the matrix-reinforcement interface. Their further research revealed that the corrosion rate of the alloy with both reinforcements was much lower than that of composites with a single

reinforcement. In their work on thermal cycling effects, Alaneme et al. found that reinforcing aluminium alloy with SiC and rice husk ash enhanced the corrosion resistance, with heat cycling playing a beneficial role in improving resistance.

In the search for alternative sources of carbon black, researchers have explored agricultural wastes, such as coconut shells, apricot stones, sugarcane, groundnut, rice husk, bagasse, nutshells, and forest residues. Coconut shells, often discarded without commercial value, are an excellent candidate for carbon black production due to their unique natural structure and low ash content. Converting these shells into activated carbon allows their use as adsorbents in wastewater treatment and drinking water purification, presenting a more cost-effective option than commercial carbon sources. Apasi et al. reinforced aluminium alloy with coconut shell ash particles and found that the wear rate of the composite materials increased with the applied load due to increased friction between the pin and disc. However, the ash reinforcement helped reduce the overall wear rate. Kumar et al. noted that adding coconut shell ash improved the hardness of the composite and reduced its density. They also observed that the inclusion of these particles influenced machining parameters, such as feed rate and depth of cut. Daramola et al. incorporated coconut shell ash into an Al 6063 alloy matrix through stir casting, and their results showed that the addition of ash increased both the hardness and tensile strength of the composites.

In the current study, graphite and coconut shell ash particles are used as reinforcements in the Al 7079 alloy matrix during the bottom pour stir casting process. The resulting composites are evaluated for their tribological properties, including specific wear rate, and their mechanical properties, such as hardness and tensile strength.

LITERATURE SURVEY

Alaneme et al. investigated the effects of thermal cycling on the corrosion behavior of aluminium alloy composites reinforced with SiC and rice husk ash. They found that thermal cycling of the composite specimens played a significant role in improving their corrosion resistance. In another area of research, numerous studies have

explored the use of agricultural waste materials, such as coconut shells, apricot stones, sugarcane residues, groundnut shells, rice husks, bagasse, nutshells, and forest by-products, to produce carbon black. Coconut shells, which are often discarded with little commercial value, pose both a disposal challenge and environmental concerns. However, their unique natural structure and low ash content make coconut shells an excellent candidate for producing carbon black. Converting these shells into activated carbon offers a sustainable solution, allowing them to be used as adsorbents in the treatment of industrial and municipal wastewater, as well as in drinking water purification. This process also reduces the costs associated with waste disposal, making it a potentially more affordable alternative to commercially available carbon products. Additionally, research has been conducted to analyze the wear properties of composites created using these materials.

Apasi et al. incorporated coconut shell ash particles into an aluminium alloy matrix and found that as the applied load increased, the wear rate of the composite materials also increased, which was attributed to higher friction between the pin and the disc. However, the addition of ash reinforcement in the matrix proved beneficial by reducing the wear rate. Kumar et al. reported that adding coconut shell ash to the composite improved its hardness while simultaneously decreasing its density. They also observed that the presence of reinforcing particles positively affected machining parameters, such as feed rate and depth of cut, during processing via stir casting.

Daramola et al. incorporated coconut shell ash into an Al 6063 alloy matrix and found that the hardness and tensile strength of the composites improved with the addition of the ash reinforcement. In the present study, graphite and coconut shell ash are utilized as reinforcements in the Al 7079 alloy matrix through the bottom pour stir casting method. The resulting composites were evaluated for their tribological properties, including specific wear rate, as well as their mechanical properties, such as hardness and tensile strength.

Bledzki et al. concluded that adding both agricultural wastes to create polymer composites increased the tensile strength by up to 80% and enhanced the composites' impact strength and elongation ability.

Alaneme et al. investigated the corrosion and wear behavior of aluminium composites reinforced with rice husk ash and alumina. Their findings indicated that the corrosion resistance of the aluminium alloy was much higher when reinforced solely with alumina compared to when rice husk ash was also included. The authors explained that this outcome was primarily due to the increased number of reinforcing particles at the interface between the matrix and the reinforcement. They also discovered that the corrosion rate of the aluminium alloy was significantly reduced when both reinforcements were used together, as opposed to when only one type of reinforcement was applied.

EXPERIMENTAL ANALYSIS

For the current study, the 99% pure aluminium alloy, Al 7079, was sourced from Fene Metallurgical in Bengaluru. Graphite and commercially available coconut shell ash were chosen as the reinforcing particles. The graphite and coconut shell ash were added to the matrix at 3% and 2% by weight, respectively, with both having a particle size of 60 micrometers. The aluminium alloy was melted using a graphite crucible heated to 750°C in an electric furnace. To eliminate moisture and prepare the particles, the reinforcing materials were first heated in a furnace. Once the metal was fully melted, degassing agents, such as hexachloroethane tablets, were introduced to remove trapped air and reduce the risk of porosity. A small amount of magnesium powder was added to the molten alloy to enhance the wettability of the reinforcing particles. While the reinforcing particles were introduced at a speed of 600–700 rpm, the molten metal was continuously stirred. To ensure proper mixing of the reinforcing particles with the matrix, the stirring process was maintained for an additional five minutes. After the mixing process, the molten metal was poured into a pre-heated mould to create the final cast composites, which measured 250 mm in length, 25 mm in width, and 35 mm in height.

Table 1. Composition of the produced composite samples

Sample Number	Composition
S1	Aluminium Alloy
S2	Aluminium Alloy + 3% CSA
S3	Aluminium Alloy + 3% CSA + 2% Gr

RESULTS AND DISCUSSION

(i) Hardness – The hardness of the composite specimens was measured using a Rockwell Hardness tester. This method was chosen due to its simplicity and the quick acquisition of results. Multiple hardness tests were performed on each specimen, and the average value was taken as the final hardness measurement. The hardness values are presented in Table 2, and a visual representation of these values is shown in Figure 1.

Table 2. Hardness of the Test Samples

Sample Number	Average Rockwell Hardness Number
S1	53
S2	59
S3	67

As illustrated in Figure 1 and Table 2, incorporating reinforcements into the alloy enhances the hardness of the resulting composite. As the matrix expands and the particle grain size continues to decrease, the hardness of the surface improves. Under high loads, the presence of durable and hard surface areas typically leads to better resistance against plastic deformation, resulting in a gradual increase in the hardness of the composites.

Table 3. XRF analysis of Coconut Shell Ash

Element	Al 2O 3	C a O	Fe 2O 3	K 2 O	Mg O	N a 2 O	Si O ₂	M nO	ZnO
%	15.6	0.57	12.4	0.52	16.2	0.45	45.05	0.22	0.3

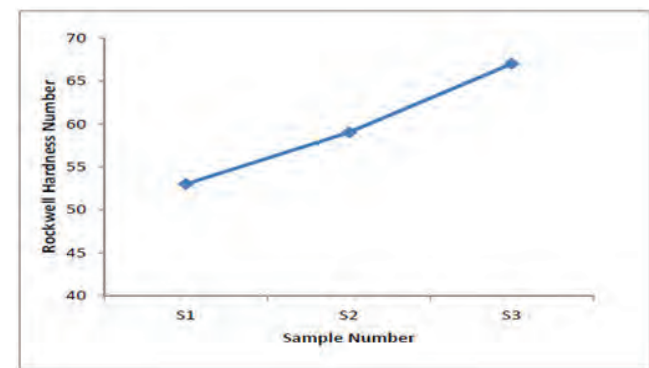


Fig. 1. Graph of Hardness of various samples

Table 3 clearly shows that the primary components of the coconut shell ash particles are SiO₂ and MgO, which are ceramic and brittle in nature and possess high inherent hardness. These tough ceramic particles are effective at absorbing much of the force applied during testing, which reduces the chances of significant surface deformation. A notable increase of 11.3% in hardness is observed between samples S1 and S2, supporting the idea that incorporating coconut shell ash particles into the Al alloy matrix enhances the hardness. When comparing sample S3 with sample S1, the hardness value increases by nearly 23%. The addition of graphite particles to the matrix further enhances the hardness, as a result of a combined effect of both direct and indirect strengthening mechanisms. These mechanisms shift the load from the weaker matrix to the harder particles, improving the interface between the matrix and particulate, which minimizes plastic deformation and increases the overall hardness of the composite.

TENSILE TEST

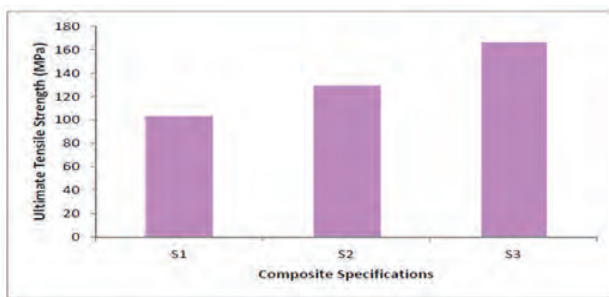


Fig. 2. Variation of UTS of the composites

The composite specimens were subjected to a tensile test to measure their maximum tensile strength. This test was performed using a PC2000 electronic tensometer with a 20 kN load capacity. The samples were secured between the jaws of the testing machine, and the results were recorded using the built-in software, which provided details such as the stress-strain curve and proof stress for tensile strength. As shown in Figure 2, the addition of reinforcing particles led to an increase in the composite's tensile strength. The ultimate tensile strength (UTS) improved by 25% from sample S1 to S2, and by 60% from sample S1 to S3. Reinforcing particles typically act as barriers to dislocation movement, increasing the strength of the matrix by resisting dislocation motion. This behavior is primarily

attributed to the strong bonding between the matrix and the reinforcing particles. The enhanced strength of the reinforcing particles contributed significantly to the higher ultimate tensile strength of the composite material.

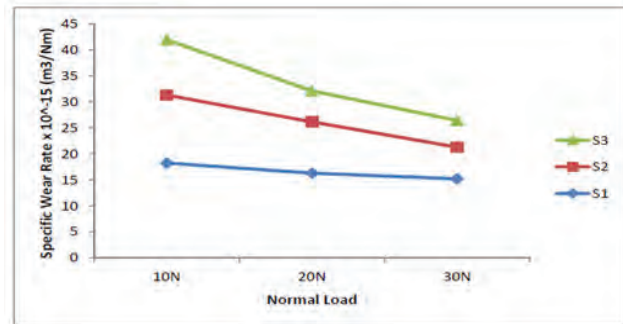


Fig. 3. Variation of Specific Wear Rate against the applied load

CONCLUSION

A new type of aluminium-based composite has been successfully developed using stir casting technology, incorporating coconut shell ash and graphite particles as reinforcements. The combined effects of these reinforcing particles led to improved hardness and tensile strength of the resulting composite specimens. This literature review highlights the potential of agricultural, industrial, and post-consumer waste as promising filler materials for both polymer and metal matrix composites. In recent years, particularly after 2015, the use of such waste materials as reinforcements for composites with desirable tribological properties has gained increasing attention. The reuse of waste materials for tribological applications offers environmental and economic benefits, enhancing the mechanical and tribological properties of the material while also reducing its overall weight. From both an ecological and financial perspective, incorporating these waste materials should be considered, as long as the wear performance of the resulting composites is comparable to that of traditional reference materials. There is a growing need to identify additional waste materials with potential for improving the tribological properties of existing materials. Future research should focus not only on large-scale waste production but also on locally available waste sources, aiming to reduce the environmental impact of the life cycle of tribological materials. A wear test conducted

on the specimen showed that the addition of coconut shell ash significantly reduced the wear rate, and the inclusion of graphite particles provided additional benefits by acting as a natural solid lubricant.

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Determination of the Performance and Emissions of a DI Diesel Engine using HCP Microalgae Biodiesel Blend with Artificial Neural Network Approach

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ABSTRACT

Performance and exhaust emission values of a DI Diesel engine were investigated by ANN modeling with the engine load 60%, 80% and 100%, IOP 200, 220 and 240 bars, IT 190, 230 and 270 bTDC, the fuel is HCP-B20 blend. In model training, cross validation and testing the actual data derived from engine test measurements was used. 30% of the data set was employed for testing the performance and remaining 70 % was randomly assigned as the training set in this model. Three neurons in input layer, nine neurons in each of the two hidden layers and five neurons in output layer. So the optimal architecture is 3-9-9-5 for the engine performance and emission model. Correlation coefficient (R) values observed in the range of 0.99782-0.99970 and mean absolute percentage error (MAPE) values observed in the range of 0.3183% for HC and NO_x are 0.362 Kg/KWh, 0.006 (% vol), 19 ppm and 144 ppm respectively at the 270bTDC IT, 240 bar IOP and 80% engine load. Experimental results and ANN predicted values are in close agreement with each other.

KEYWORDS : HCP microalgae, ANN, IOP, IT.

INTRODUCTION

For the prediction of the engine performance and emissions ANN approach is widely used. So in this study ANN model was used to predict the values. Correlation coefficient (R) and coefficient of determination (R²) have been considered to assess forecasting performance of the proposed ANN models [Roy S. et., al. (2014), Cay Y. et.,al. (2012), Nazafi G. et, al. (2009)].

LITERATURE REVIEW

Nazafi G. et, al. (2009), Cay Y. et.,al. (2012) and Canakci (2006) and Ismail HM et.,al.(2012) assessed proposed models using error measurement standards of Mean Squared Error (MSE), and Root Mean Squared error (RMSE) and Mean Absolute Percentage Error (MAPE). Literature related to Sayin C. et, al. (2007),

Nazafi G. et, al. (2009) and Ismail HM et.,al.(2012), for the engine out responses MAPE of 5% was considered as the limit. According to the studies of Canakci, Erdil, and Arcaklioglu 2006; Arcaklioglu 2004; Arcaklioglu and Celikten 2005., ANN was used to predict the characteristics of diesel engine performance and emissions under the effect of injection pressure.

METHODOLOGY

ANN predictions performance are measured by comparing the predictions with the experimental results which were not used in the training process. In the model, as the training set 70% of the data set is randomly assigned. For the performance of ANN prediction, the remaining 30% of the data set is employed. It is observed that the ANN model can predict the engine performance.

Table 1: Details of network parameters developed on MATLAB

MATLAB	
Topology	3 inputs 5 outputs and 2 hidden layers with 9 hidden neurons in each layer.
Data	Training Subject : 70% randomly selected observation data Test Subject : 30% randomly selected observation data
Activation	Log-sigmoid
Training algorithm	Forward Back Propagation.
Loss function	Minimum MSE.
Stopping Criteria	Stop the Network Training when the variation errors starts increasing.

Table 2: Experimental data for modelling ANN

Parameter settings			Characteristics				
IT (bTDC)	IOP (bar)	Load (%)	BTE (%)	BSFC (Kg/KWhr)	CO (ppm)	HC (ppm)	NOx (ppm)
19	200	60	27.65	0.392	0.017	19.5	137
19	200	80	30.5	0.398	0.013	21.4	159
19	200	100	30.9	0.386	0.014	24.6	212
19	220	60	27.72	0.382	0.016	19.2	135
19	220	80	30.68	0.388	0.012	21.2	161
19	220	100	30.88	0.378	0.013	24.1	201
19	240	60	27.83	0.364	0.015	18.9	127
19	240	80	30.82	0.374	0.011	21.1	155
19	240	100	31.1	0.366	0.012	23.7	197
23	200	60	28.03	0.385	0.016	18.6	148
23	200	80	31	0.39	0.012	21	171
23	200	100	31.3	0.38	0.014	23	222
23	220	60	28.2	0.374	0.013	17	142
23	220	80	31.3	0.38	0.01	19	165
23	220	100	31.55	0.371	0.011	21	208
23	240	60	28.58	0.359	0.012	16.4	126
23	240	80	31.6	0.368	0.011	18.8	147
23	240	100	31.85	0.361	0.01	20.7	190
27	200	60	28.81	0.376	0.014	18.8	134
27	200	80	31.7	0.383	0.011	20.9	154
27	200	100	31.9	0.372	0.012	23.9	207
27	220	60	28.9	0.37	0.009	18.5	131
27	220	80	31.79	0.375	0.01	21	150
27	220	100	31.89	0.364	0.011	22.1	196
27	240	60	28.98	0.351	0.008	15.2	122
27	240	80	31.98	0.356	0.007	16.0	145
27	240	100	31.87	0.361	0.009	18.1	186

The success of any ANN model depends upon a clear understanding of the problem under consideration and

identification of the vital process control variables to be modelled. The ANN models was developed using steady state experimental data to predict BTE, BSFC,CO,HC, NOX, with blend percentage, IOP and IT as input parameters. The optimal architecture for proposed model is shown in figure 1.

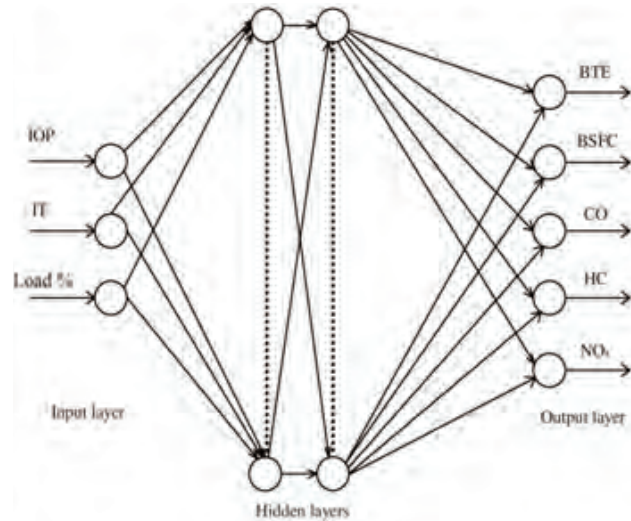


Fig. 1: Architecture of proposed ANN

Mean squared error (MSE) is chosen as the performance function to be minimized. MSE bears the very satisfying features of convexity, symmetry and differentiability and an excellent metrics in the context of optimization. (Cay et al.(2012) and Najafi et al.(2009)) The developed model has been tested against statistical errors viz., root-mean-square error (RMSE) and mean absolute percentage error (MAPE) and are provided in Table 3.

Table 3: Fraction of variance (R²), RMSE and MAPE values

Parameters	R ²	RMSE	MAPE
BTE	0.99942	1.0246	0.80
BSFC	0.99746	0.8702	0.86
NO _x	0.99857	0.7245	0.46
CO	0.97964	1.1287	1.24
HC	0.99566	0.8988	1.08

The ANN is repeated for five times to find out ideal inputs for the maximum and minimum values of the given output parameters with higher accuracy than readings. The correlation coefficient (R), mean absolute percentage error (MAPE) and root mean squared error

(RMSE) values for the proposed ANN model was observed in the range of 0.9896–0.99970, 0.45–1.24% and 0.7245–1.1287 respectively. The results obtained by ANN for the engine performance studies were impressive. The ability to predict BTE, BSFC, NO_x, CO & HC was commendable. Figure 3 indicates the steady and admirable concurrency of the network over the entire range of operation. Further, it indicates the innate sensitivity and toughness of the network in its ability to map the performance and emission values simultaneously with excellent accuracy. Good statistical performance was yielded with the ANN predictions for the performance and emissions of the tested engine.

RESULTS AND DISCUSSION

Figures from 2 to 6 depict the consistent and appreciative agreement of the network forecasted values in response to the experimental results for performance as well as emissions.

Brake thermal efficiency

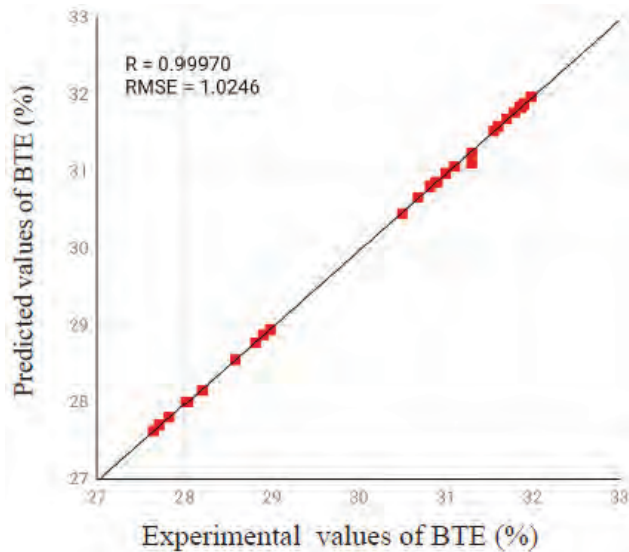


Fig. 2: Comparison of ANN predicted BTE with experimental (target) values

Figure 2. represents the prediction of ANN on BTE is in persistent with the experiment results in all cases. ANN predicted BTE values when compared with the experimental BTE results have R2, RMSE and MAPE values of 0.99942, 1.0246 and 0.8, respectively. The predicted maximum BTE was observed to be 31.83% at IT of 27obTDC with IOP 240 bar at 80% engine load,

while minimum BTE was predicted as 27.62 % at IT of 19obTDC with IP of 200 bar at 60% engine load.

Brake specific fuel consumption

Prediction of ANN on BSFC is represented in the figure 3.. Predicted values are in persistent with the experiment results. ANN predicted BSFC results when compared with experimental BSFC results have R2, RMSE and MAPE values as 0.999746, 0.8702 and 0.86, respectively. The predicted minimum BSFC was observed to be 0.362 Kg/KWh at IT of 27obTDC with IOP 240 bar and at 80% engine load while maximum BSFC was predicted as 0.399 Kg/KWh at IT of 19obTDC with IOP 200 bar and at 60% engine load.

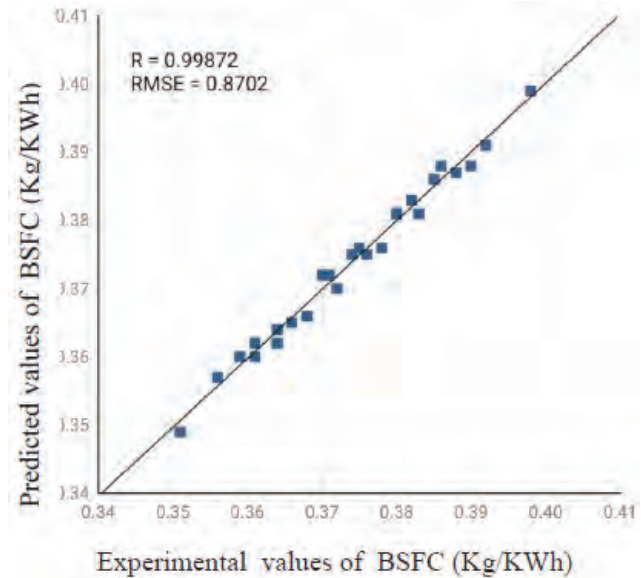


Fig. 3: Comparison of ANN predicted BSFC (Kg/KWh) with experimental (target) values

Carbon monoxide emissions

Figure 4 represents the prediction of ANN on CO emissions, which is in persistent with the experimental results in all cases.

ANN predicted CO results when compared with experimental CO results have R2, RMSE and MAPE values of 0.97964, 1.1287 and 1.24 respectively. At the IT of 7obTDC with IOP 240 bar and at 80% engine load the predicted minimum CO value of 0.006(%vol) and maximum CO is predicted as 0.016 (%vol) at 19obTDC IT, 200 bar IOP and 80% engine load.

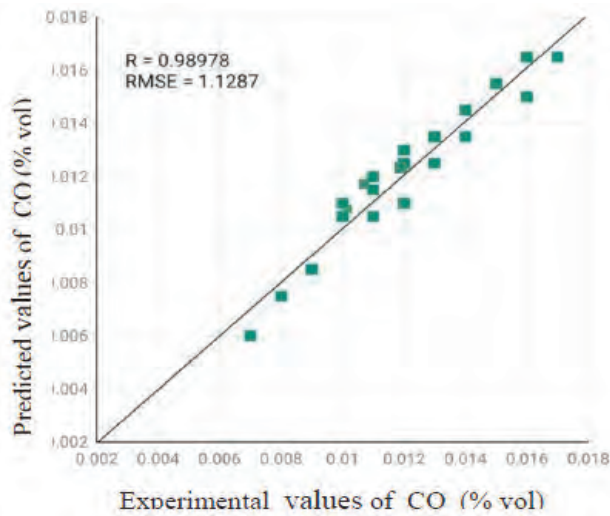


Fig. 4: Comparison of ANN predicted CO (%vol) values with experimental (target) values

Un burnt hydrocarbon emissions

Figure 5. represents the prediction of ANN on HC emissions, The ANN predicted HC (ppm) are in appreciative agreement with experimental (target) values. R2, RMSE and MAPE values are 0.99566, 0.8988 and 1.08 respectively when compared the ANN predicted HC results with experimental HC results. The predicted minimum HC is observed to be 19 (ppm) at 27obTDC IT, 240 bar IOP and 80% engine load. And the maximum HC is predicted as 24.7 (ppm) at IT of 19obTDC with IOP of 200 bar and at 100% engine load.

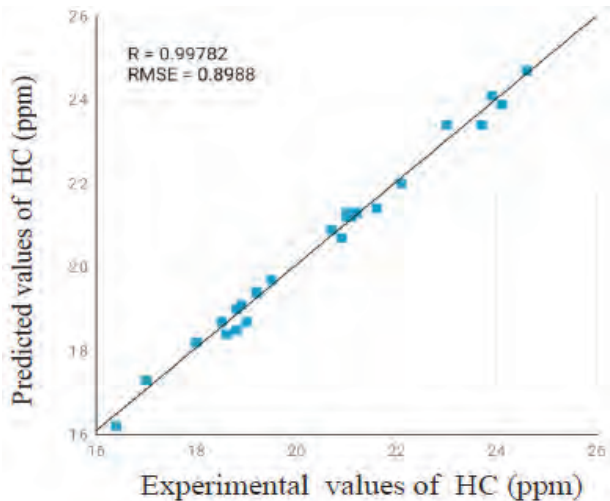


Fig. 5: Comparison of ANN predicted HC (ppm) with experimental (target) values

Oxides of nitrogen (NOx)

Figure 6. represents the comparison of ANN predicted NOx (ppm) with experimental (target values). ANN predicted results when compared with experimental results have R2, RMSE and MAPE values of 0.99857, 0.7245 and 0.46, respectively. At the 270bTDC IT , 240 bar IOP and 80% engine load the minimum NOx predicted is 144 (ppm), while the maximum NOx 220 ppm is predicted at IT 23obTDC with IOP of 200 bar and at 100% engine load.

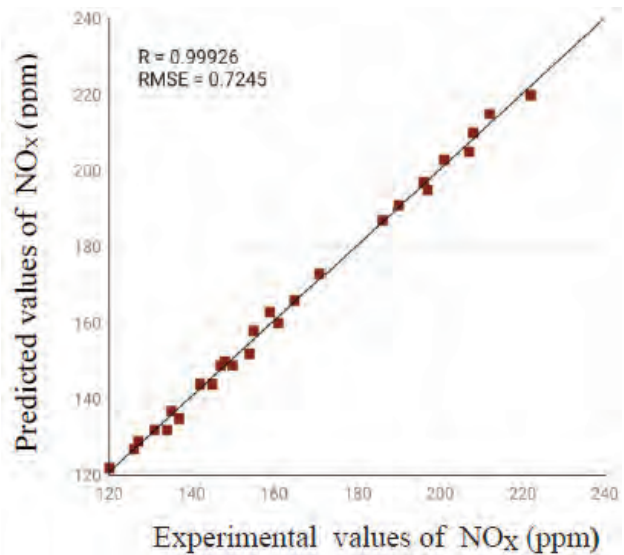


Fig. 6: Comparison of ANN predicted NOX (ppm) with experimental (target) values

CONCLUSION

In this study, ANN model is prepared for the validation. ANN has been used to map the experimentally obtained data. The model exhibited an impressive agreement as correlation coefficient (R) and mean absolute percentage error (MAPE) values observed in the range of 0.99782–0.99970 and 0.80–1.24% respectively with remarkably low RMSEs.

ANN architecture with three neurons in input layer, nine neurons in each of the two hidden layers and the output layer having five neurons (3-9-9-5) is the optimal architecture for the performance and emission model. It provides a complete platform in predicting the virtual sensing in optimizing the real time with established ANN architecture. Statistical analysis shows that the ANN predicted and experimental results are in close

agreement with each other. The ANN predicted values of BTE, BSFC, CO, HC and NO_x are 31.83%, 0.362 Kg/KWh, 0.006 (%vol), 19 ppm and 144 ppm respectively.

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Evaluation of Mechanical and Wear Assessment of AL-0.60-SI-1.0-MG-0.28-CU/Alumina MMCS for Industrial Applications

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ABSTRACT

Aluminium alloy cans are widely used in the food market to store food instead of traditional glass jars, bottles, and steel cans. Aluminum's special mechanical qualities, such as its nimble bulk, ductility, and decay resistance, have influenced this movement. Saddling the superior quality and wear capacities of renowned engineered fortifications—such as those that are lightweight and require little preparation work—is the foundation of the outline concept. The outline of AMCs using fortifications of agricultural waste slag has hardly been discussed in any literature. The SEM pictures of shiny samples were analysed. The distribution of alumina (Al_2O_3) strengthening specks is found to be stable. The grain borders do not contain all of the alumina particles. In both untreated and extruded settings, wear testing of Al6061 alloy revealed greater surface wear than Al6061/ Al_2O_3 composites. In contrast to the wear surface morphology of Al6061/ Al_2O_3 composites, the wear surface morphology of Al6061 alloy exhibits a rough surface with more ridges and grooves.

KEYWORDS : Al6061 alloy, Alumina, Fracture surface, Tensile strength, MMCs.

INTRODUCTION

In the food economy, aluminium alloy cans are broadly used for food storage in place of customary glass jars, bottles, and steel cans. This trend is shaped by aluminum's unique mechanical properties, which include nimble bulk, ductility, decay resistance. Wear tests of Al6061 alloy showed more surface wear than Al6061/ Al_2O_3 composites in both untreated and extruded settings. The wear surface morphology of Al6061 alloy shows a rough surface with more ridges and grooves than the wear surface morphology of Al6061/ Al_2O_3 composites.

SiC with Al_2O_3 , for instance. Saddling the superior quality and wear capacities of renowned engineered

fortifications—such as those that are lightweight and require little preparation work—is the foundation of the outline concept. The outline of AMCs using fortifications of agricultural waste slag has hardly been discussed in any literature. Usability

Metal Matrix Amalgams

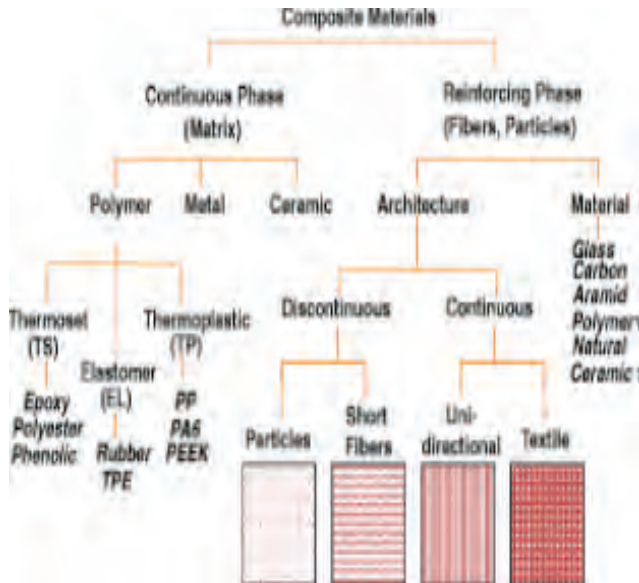
Around trio forms of metal matrix mixes are there which are as follows:

- Speck armored amalgams
- Diminutive fiber or whisker armored amalgams
- Incessant fiber or sheet armored amalgams

These three types can alternatively be categorised as

continuously bolstered amalgams and occasionally bolstered MMCs. Particle-bolstered amalgams are enlightened in their application and advantages, however I won't go into depth about the latter two types. While reciting amalgam process strategies, the process of sporadically bolstered amalgams is the subject of the current study.

Applications of Composite Materials



LITERATURE SURVEY

Narayan et al. [39] Metal-framework composites are a type of blend in which granules or fibers are implanted into a metal or earthenware product to improve its properties. Aluminum nanoparticles is a crucial creating now with used in the aerospace industry for the fabrication of a wide range of components. In particular, its high quality to thickness ratio makes it a sought-after steel sections matrix.

Lashgari et al. [32] “analysed the automated conduct of Al alloy old because the milieu, for the underpinnings. Cinders is that the solely agronomic waste that contains the loftier mass of silicon dioxide in it. “This tryout results showed that an honest inflexibility and strength of those fused will notice application wherever light-weight materials square measure alleged to be needed”. The inflexibility of ready fusions is hyperbolic by bolstering.

METHODOLOGY, MATERIALS AND METHODOLOGY

Methodology Flowchart

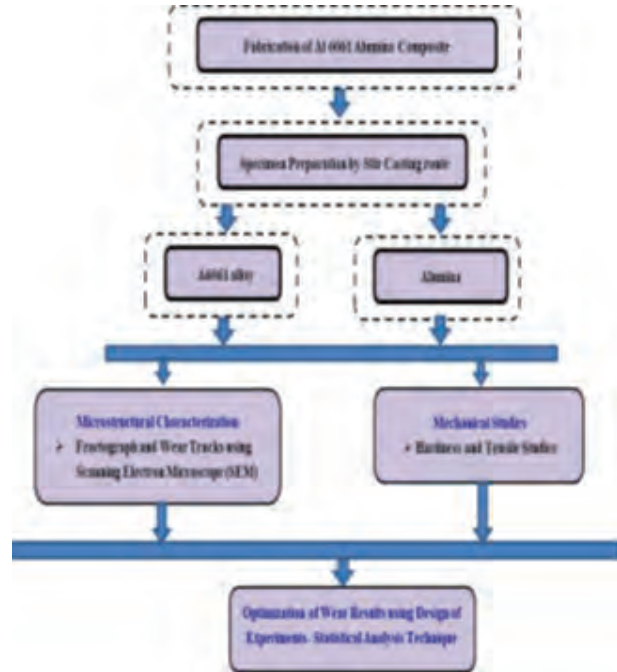


Fig. 1: Experimental Flowchart of Al Composites

Al6061 alloy

- Al 6061 is a widely used grade of aluminium alloy that is produced in numerous forms for a range of uses. Examples of this include extrusions and A6061 plates. For applications like furniture, boats, and general engineering, it is often the preferred alloy.

Al2O3 as Reinforcement Material

- Alumina, often known as Al₂O₃, is a chemical compound made up of Al and O₂. Al₂O₃ (III) is a common name for some aluminium oxides. Although it is commonly known to as alumina, depending on its type or use, it can also be called aloxide, aloxite, or alundum.

Designation of Alumina Reinforced Alloy

- Stir casting will be used to create the composites needed for this study. This study will result in a final composite with a dynamic proportion breakdown of Al₂O₃ (5, 7, and 9 by Wt%).

Table 1: Designation of Alumina Armoured Alloy

S/No	Designation of Alloy/Composite (Before Extrusion)	Designation of Alloy/Composite (After Extrusion)
1	As-Cast (Al6061 alloy)	As-Cast (Al6061 alloy)-E
2	Al6061 alloy + 5 % Al ₂ O ₃	Al6061 alloy + 5 % Al ₂ O ₃ -E
3	Al6061 alloy + 7 % Al ₂ O ₃	Al6061 alloy + 7 % Al ₂ O ₃ -E
4	Al6061 alloy + 9 % Al ₂ O ₃	Al6061 alloy + 9 % Al ₂ O ₃ -E

Stir Casting Process

- Liquid metallurgy has been used for casting (Stir Casting Technique). According to the reinforcing ratios, Al 6061 billets are divided into pieces and weighed in a weighing pan. Alumina particles are subsequently preheated in a different furnace. After heating the pieces of aluminium billets in a furnace, alumina is added, mixed, and then poured into a cast iron mould.



Fig. 2: Stir Casting Setup

Microstructure Characterization using SEM

For microscopic inspections, a well-prepared specimen and magnifications are required. A strict, step-by-step procedure is necessary for the proper preparation of the requirements and material surfaces. To create a silvery surface that is resistant to scratches, the samples are cut into small pieces and polished using emery paper. Images are taken when the polished surface is put under a scanning electron microscope.



Fig. 3: SEM Setup

Hardness and Tensile Test



Fig. 3: Hardness Testing Machine Setup



Fig. 4: Tensile Testing Machine Setup

In tensile testing the sample is placed between two jaws of tensile clamp and load is applied through the load cell. Slowly the material gets stretches and breaks and measured across the specimen according to ASTM standard procedure.

RESULTS AND DISCUSSION

Microstructure Analysis of Al6061/Alumina (Al2O3) Composites

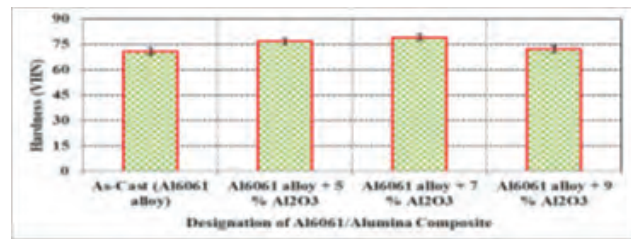
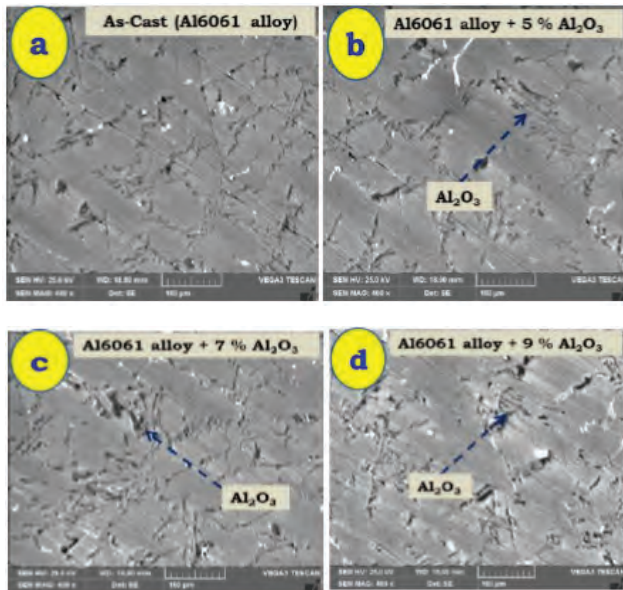


Fig. 5: Hardness Test Values of Al6061- Al2O3 MMC's (before Extrusion)

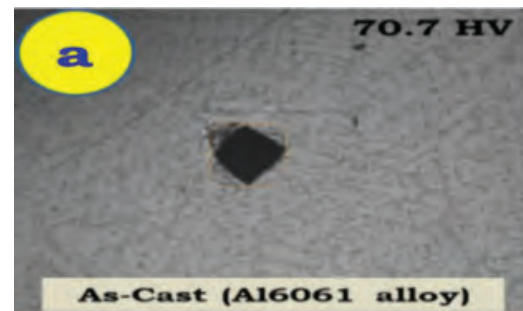


Fig. 6: (a) Hardness Test Indentation result of Aluminium 6061 alloy

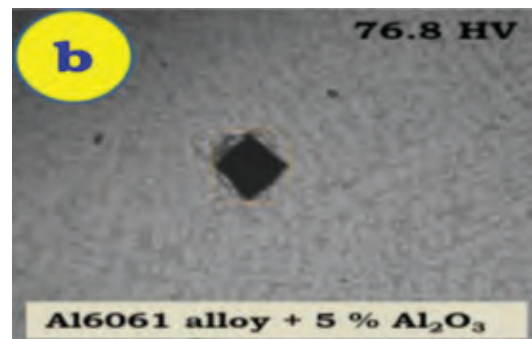


Fig. 6: (b) Hardness Test Indentation Al 6061 alloy + 5% Al2O3

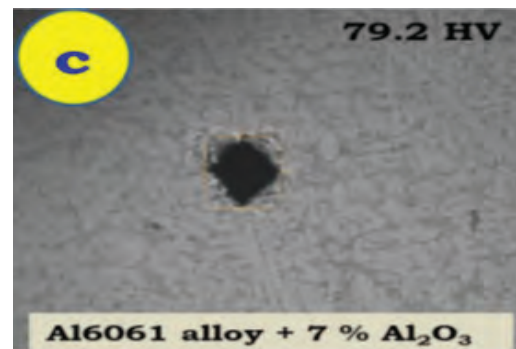


Fig. 6: (c) Hardness Test Indentation result of 6061 Al 6061 alloy + 7% Al2O3

Hardness Test Results of Al6061/Alumina (Al2O3) Composites before Extrusion

Table 2: Hardness Test Values Al6061/Alumina (Al2O3) Composites before Extrusion

S/No	Alloy/Composite	Diagonal X(mm)	Diagonal Y(mm)	Hardness VHN	% Improvement in Hardness
1	As-Cast (Al6061 alloy)	0.115	0.114	70.7	----
2	Al6061 alloy + 5 % Al2O3	0.127	0.123	76.8	8.62
3	Al6061 alloy + 7 % Al2O3	0.126	0.127	79.2	12.02
4	Al6061 alloy + 9 % Al2O3	0.122	0.120	72.4	2.40

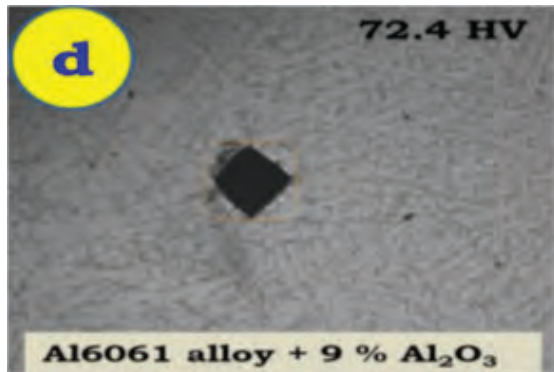


Fig. 6: (d) Hardness Test Indentation result of Al 6061 alloy + 9% Al₂O₃

Hardness Test Results of Al6061/Alumina (Al₂O₃) Composites after Extrusion

Table 3: Hardness test values Al6061/Alumina (Al₂O₃) Composites after Extrusion

S/No	Alloy/Composite	Diagonal X(mm)	Diagonal Y(mm)	Hardness VHN	% Improvement in Hardness
1	As-Cast (Al6061 alloy)-E	0.105	0.104	80.1	----
2	Al6061 alloy + 5 % Al ₂ O ₃ -E	0.117	0.103	83.3	3.99
3	Al6061 alloy + 7 % Al ₂ O ₃ -E	0.116	0.107	88.7	10.73
4	Al6061 alloy + 9 % Al ₂ O ₃ -E	0.112	0.107	85.5	6.74

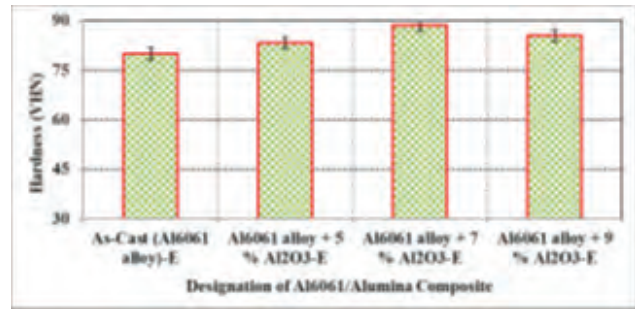


Fig. 7: Hardness test values of Al6061- Al₂O₃ MMC's (after Extrusion)

CONCLUSIONS AND FUTURE WORK

The following conclusions were demonstrated on Al₂O₃-armored Al6061 alloy:

The following was looked at in the SEM pictures of shining samples

- The distribution of alumina (Al₂O₃) strengthening specks is found to be stable.
- The grain boundaries do not contain alumina particles.
- Alumina flakes have improved the mechanical characteristics by soaking well in the matrix.

Alumina particles as corroboration helped raise Al6061's hardness (VHN) from 70.7 according to the following: (Prior to Extrusion)

- 5% Alumina: 76.8 (an increase of 8.62%)
- 7% Alumina: 79.2 (12.02% increase)
- 9% Alumina: 72.4 (2.40% increase)

Alumina particles as confirmation helped raise Al6061's hardness (VHN) from 80.1 according to the following: (Following Extrusion)

5% Alumina: 83.3 (3.99% increase) 7% Alumina: 88.7 (10.73% increase) 9% Alumina: 85.5 (6.74% increase)

According to the following, alumina specks as confirmation helped raise the UTS (MPa) of Al6061 from 105.2 (MPa): (Prior to Extrusion)

- 5% Alumina: 201.5 (MPa) (an increase of 13.87%)
- 7% Alumina: 209.7 (MPa) (35.45% increase)
- 9% Alumina: 217.2 (MPa) (31.27% increase)

Alumina specks as verification helped raise Al6061's UTS (MPa) from 200.1 (MPa) according to the following: (Following Extrusion)

5% Alumina: 225.4 (MPa) (12.64% increase) 7% Alumina: 261.25 (MPa) (30.53% increase) 9% Alumina: 252.4 (MPa) (26.13% increase)

In comparison to Al6061/Al₂O₃ composites under both untreated and extruded circumstances, wear studies of Al6061 alloy revealed more surface wear.

Wear surface morphology of Al6061 alloy shows a rough surface with more grooves and ridges compared to wear surface morphology of Al6061/ Al₂O₃ composites.

APPROACHING WORK

1. By varying the cutting circumstances (material removal rate, feed rate, etc.), the formability of Al6061 alloys with varying Al₂O₃ proportions can be investigated.
2. Al6061 and Al₂O₃ Composites can be subjected to heat treatment evaluations for a variety of factors.

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Experimental Investigation on Replacement of Steel Rebars with Basalt Rebars in Concrete Beams

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ABSTRACT

This paper investigates ultimate failure load of BFRP rebar concrete beam, steel rebar reinforced concrete beam and hybrid rebar reinforced concrete beam (BFRP rebar and steel rebar). Concrete beams were tested on loading frame to find out ultimate failure load and it was found that beam with hybrid rebar having BFRP rebar and steel rebar showed greater resistance to failure compared to beams with conventional steel rebars and BFRP rebars.

KEYWORDS : *Basalt fiber reinforced polymer rebar, Steel rebars, Hybrid rebar beams, Green fiber.*

INTRODUCTION

Paul Dhe, who obtained U.S. patent 1,462,446 in 1923, made 1st attempt to manufacture basalt fiber in US. Following World War II, researchers from Soviet Union, Europe, US continued to develop them, particularly for use in military and aerospace applications. Basalt fibers were employed in broad spectrum of civilian utilizations since their declassification in 1995.

Basalt rock used to make basalt rebars is derived from flood volcanoes and volcanic magma, which is a highly hot fluid or semi-fluid substance that solidifies in open air. One type of dark-colored, grey volcanic rock is commonly referred to as basalt. Minerals olivine, pyroxene, plagioclase make up majority of basalt. Basalt may naturally produce nucleating agent when heated to high temperatures, which is important for material's thermal stability. In comparison to other materials, this results in improved volumetric integrity. A type of mineral fiber generated from basalt is called basalt fiber. It is only green fiber and pollution-free. Because of their similar densities to Ordinary Concrete (OC), they can be more efficiently wrapped together to enhance mechanical properties and extend concrete's service life. Three primary effects of fibers on concrete matrix are reinforcement, toughening, crack resistance.

BFRC has developed into hotspot for civil engineering structure research in recent years. Basalt (BFRC), a recently developed material, is emerging as steel rebar substitute. When compared to steel rebars, BFRC extracted from crude lava has beneficial mechanical and physical characteristics like light weight, high elastic modulus, high corrosion resistance to adverse conditions, high tensile strength, good frost resistance, simple processing, nonmagnetic qualities. Additionally, as compared to carbon (CFRC), BFRC exhibits superior ductility and fire resistance.

Researchers initiated researching basalt rock, and they discovered a method for producing continuous basalt fiber by melting rock at temperatures between 1500-1700°C. Fibers can also be used to make rods, mats, nets, straps, sheets, chopped fiber. Application of basalt fiber in construction sector is expanding rapidly. Survey of literature reveals that integrating basalt fibre into concrete has great potential to increase its strength. When compared to steel fiber, it has a greater tensile strength.

LITERATURE REVIEW

Saravanan & N.S. Rohit b Reddy, Prof-Dr. S-Elavenil (2017): Flexural strength character and strains occurring

in concrete and effective percentage are the components that are preferred in tests conducted on basalt reinforced concrete (RC) beams. Such basalt RC beams used in this experiment are totally 6 specimens. Using M30 grade concrete, flexural behavior of basalt RC beams was enhanced to be 2-3% and capacity of load carrying increased upto 12% in comparison with flexural behavior and load carrying capacity of steel RC beams such as control beams. Again, in comparison with control beam specimens, the specimens that are reinforced with both basalt rebars and steel rebars showed their flexural behaviour enhancement and capacity of load carrying up to 27% and 15%, respectively. While in all the specimens same M30 grade concrete is used.

Ramakrishnan and others (1998): To study how the basalt bar reinforced concrete structures perform or behave they have conducted few experiments. Purely fresh and hardened properties were put to test and studied for fresh concrete properties test program or experiments like air content, vee bee slump, slump concrete temperature, unit weight. Behavior of structures after cracking and toughness indices of concrete as per American society for testing and materials (ASTM), flexural strength of concrete structure, load deflection behavior, compressive strength, comparison between curves of load-deflection, elastic modulus are decided to be the components of hardened concrete. The results of the experiment explain that without any muddle, extending or falling apart concrete and basalt fiber can be mixed properly and easily and also due to adding basalt fiber observation is made that the capacity of energy consumption after cracking and ductility is increased.

Preetha Prabhakaran and others (2016): In this study both flexural strength of concrete beams along with axial load of columns reinforced with both conventional steel and BFRP bars is studied. Casting of 12 beams and 6 columns which were put to test and will be studying outcome of experiment. Tension bars taken in the testing beams are 2 bars and total of 3 bars are taken as tie members in column. 4 linear bars in a one kind of specimen are used. The outcomes were such that beams improved under flexural strength widely and largely but in the outcome of column specimen it was observed that

the basalt reinforced column couldn't carry axial load any better and is comparatively low than the columns reinforced with steel bars.

Sudha et al. (2019): examined mechanical characteristics of basalt-reinforced concrete at beam-column joints like its compressive or split tensile strengths. Under cyclic loads, behavior of beam column joints consisting 0.75%, 1%, 1.25% basalt fiber was investigated. The results demonstrated that integration of basalt fibers improves performance of beam-column joint. According to study's findings, adding basalt fiber to concrete will improve its flexural strength, split tensile strength, toughness, compressive strength. Additionally, this shall decrease size of cracks when they fail.

METHODOLOGY

In this research the physical properties of materials are studied such as cement, M-sand, coarse aggregate was tested individually.

Cement Portland pozzolana cement of ultratech brand was used in present investigation with normal consistency 32% and specific gravity 3.15.

Fine Aggregate Locally available M-sand was used in the present investigation with specific gravity 2.56 and fineness modulus 3.66.

Coarse aggregate Crushed rounded aggregates 20mm downsize were used in present investigation with specific gravity 2.7 and water absorption 1.34%

Water Portable water has been utilized in investigation for mixing & curing.

Mix Proportions M30 grade concrete has been mixed utilizing IS 10262:2009 and mix proportion has been obtained as follows:

Cement = 440 kg/m³

Water = 198 lit

M-sand = 746.8kg/m³

Coarse aggregate = 1002.45kg/m³

Water-Cement ratio = 0.45

C: M-sand: C.A = 1 : 1.69 : 2.27.

Specifications

Sl. No	Specimen	Beam Size (Mm)	Reinforcement Details
1.	Beam reinforced with basalt rebars. (BFRP beam) (B1)	1000X150X230	2#12mm@ TOP, 2#12@ BOTTOM, 2L 8mm stirrups @150mm c/c
2.	Beam reinforced with steel rebars. (STEEL rebars beam) (B2)	1000X150X230	2#12mm@ TOP, 2#12@ BOTTOM, 2L 8mm stirrups @150mm c/c
3.	Beam reinforced with basalt rebars at tension zone and steel at compression zone. (Hybrid beam) (B3)	1000X150X230	2#12mm@ TOP, 2#12@ BOTTOM, 2L 8mm stirrups @150mm c/c



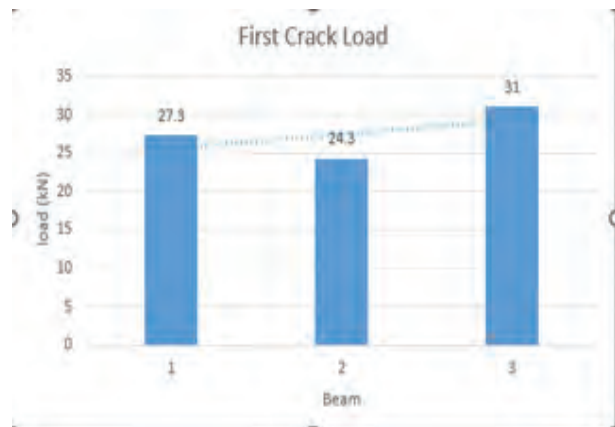
OBJECTIVE OF THE PROPOSED RESEARCH

- To know the influence of basalt rebar on the behavior of RC beams.
- To determine the ultimate cracking load of basalt rebar concrete beams, hybrid rebar concrete beam (steel rebar and BFRP rebar)
- Compare the results with steel rebar reinforced concrete.



RESULTS AND DISCUSSION

Beam	Initial load (kN)	First crack reading (kN)	Ultimate load reading (kN)
B1	0.9	27.3	32.5
B2	0.5	24.3	37.3
B3	0.4	31	57.5





From graph of first crack load as well as ultimate failure load, this can be seen that compared to Beam1 and beam2 first crack load as well as ultimate failure load for beam3 is high.

It is also seen that first crack load for BFRP rebar beam is high than Steel rebar beam and hybrid rebar beam with steel rebar in compression zone and BFRP rebar in tension zone of concrete has exhibited greater resistance to initial cracking.

High tensile strength of BFRP rebars results in higher ultimate failure load when used in tension zone.

CONCLUSION

- When hybrid rebars with steel rebars in compression zone and BFRP rebar in tension zone concrete beam has shown higher resistance to cracking and ultimate failure.
- BFRP rebars can be effectively used as rebars in concrete beams.
- First crack load for hybrid rebar beam is 27% higher than steel rebar concrete beam.

- Ultimate failure load for hybrid rebar beam is 54% higher than steel rebar concrete beam.

SCOPE FOR FURTHER STUDIES

- Bond strength of concrete and BFRP beams can be studied.
- Durability studies of BFRP beams can be carried out.
- Concrete design with use of BFRP rebars has to be investigated.

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The Impact of BIM on a Residential Design Quality

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ABSTRACT

This paper investigates the effectiveness of Building Information Modeling (BIM) in improving design efficiency in residential construction, compared to traditional Automated Computer-Aided Design (AutoCAD) methods. BIM offers advanced tools for data integration and team collaboration, which help streamline the design process and enhance project outcomes. The study identifies key differences between BIM and AutoCAD in terms of design accuracy, workflow efficiency, and information management. Additionally, the paper examines BIM's Influence on construction timelines, cost saving, error reduction, and multidisciplinary coordination. The findings highlight BIM's growing significance in meeting sustainability goals and evolving client demands, positioning it as a valuable asset in modern residential construction.

KEYWORDS : *Building information Modeling, AutoCAD, Residential construction.*

INTRODUCTION

The Architecture, Engineering and Construction (AEC) industry has undergone rapid transformation through the adoption of digital technologies. Many years, Computer Aided Design software, such as AutoCAD, has been the primary tool for creating technical drawings and simple 3D models. CAD programs provide accurate design documentation but often operate in isolation, lacking real time data integration and collaboration capabilities. This limitation can lead to inefficiencies, miscommunication, and errors during the construction process, especially in complex residential projects involving multiple stakeholders.

Building Information modeling (BIM) addresses these challenges by offering a comprehensive, data rich platform that combine 3D modeling with detailed information about building components, timelines, costs and more. BIM facilitates detail collaboration among architects, engineers, contractors and clients by providing a single shared model that integrates all aspects of the building lifecycle- from design and construction

to operation and maintenance. This integration helps reduce errors, optimizes schedules, control budgets and support sustainable building practices.

In residential construction, BIM's capabilities offer significant advantages over traditional CAD methods. It improves visualization, enhances interdisciplinary coordination, and supports better decision-making through data-driven insights. As the demand for faster, cost-effective, and ecofriendly housing grows, understanding the role of BIM in streamlining design and construction process becomes crucial.

LITERATURE REVIEW

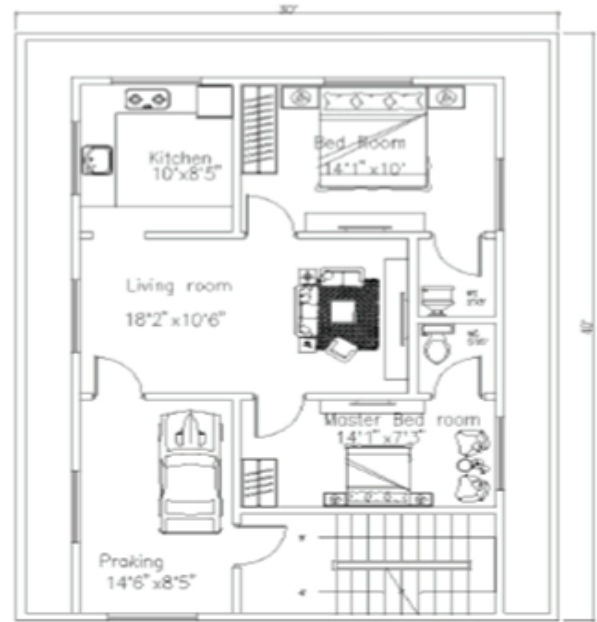
Building Information Modeling (BIM) is transforming the architecture, engineering, and construction (AEC) industry by offering superior visualization, data integration, and collaboration compared to traditional CAD. In India, studies have examined BIM'S adoption and its challenges. Jagadeesh and Jagadisan (2019) found low adoption due to limited awareness and training. Ahuja et. al. (2016) used the TOE framework

to show that while firms see BIM’s value, organizational and regulatory barriers remain. Giel and Issa (2013) confirmed similar benefits in a Pune case study but noted a lack of industry- wide documentation. Mahajan and Narkhede (2023) reviewed Indian BIM research and stressed the need for policy and educational support. Raj et al. (2025) highlighted that India’s BIM use in sustainable construction still lags due to limited awareness and policy gaps. Overall, BIM shows strong potential for residential construction in India.

METHODOLOGY

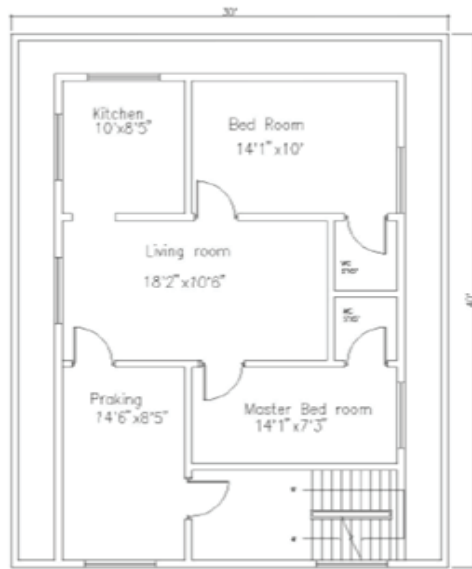
This study compares the use of AutoCAD and BIM using Revit to check which one is faster and more efficient in designing A G+2 residential building. The building used in this study includes several 2BHK and 3BHK flats, staircases, and utility spaces.

Two models of the same building were created: one using AutoCAD and the other using Revit. Both models followed the same design plan to make the comparison fair. The time taken to complete different tasks was noted, such as how long it took to create the drawings, make changes, coordinate between architecture and engineering, and prepare final documents like floor plans and elevations.



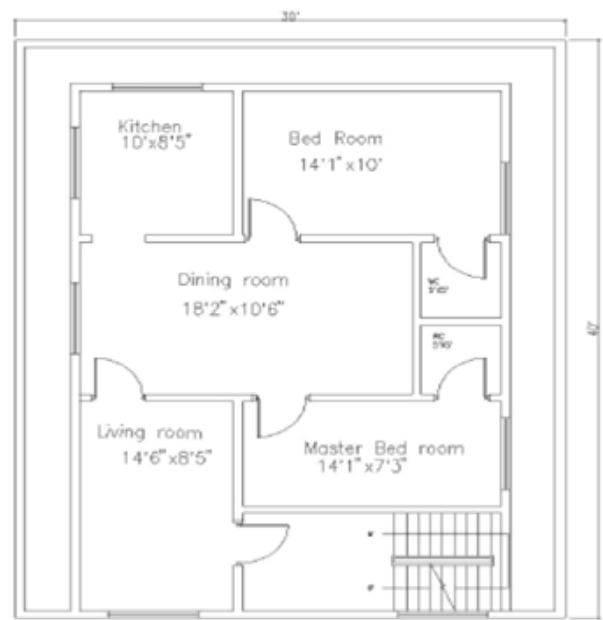
Ground Floor

Fig. 2. Ground floor plan of Residential Building in Revit Software



Ground Floor

Fig. 1. Ground floor plan of Residential Building in AutoCAD Software



First Floor

Fig. 3. First floor plan of Residential Building in AutoCAD Software

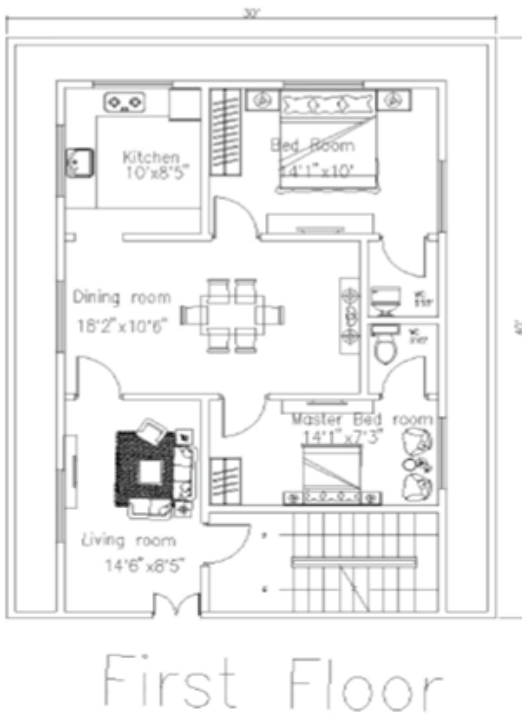


Fig. 4. First floor plan of Residential Building in Revit Software

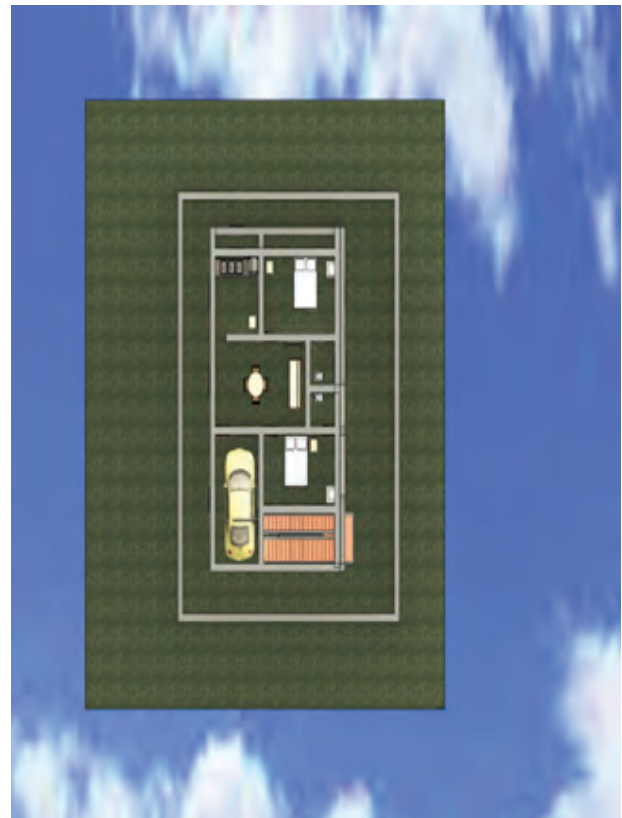


Fig. 6. Top View of Residential Building in Revit software

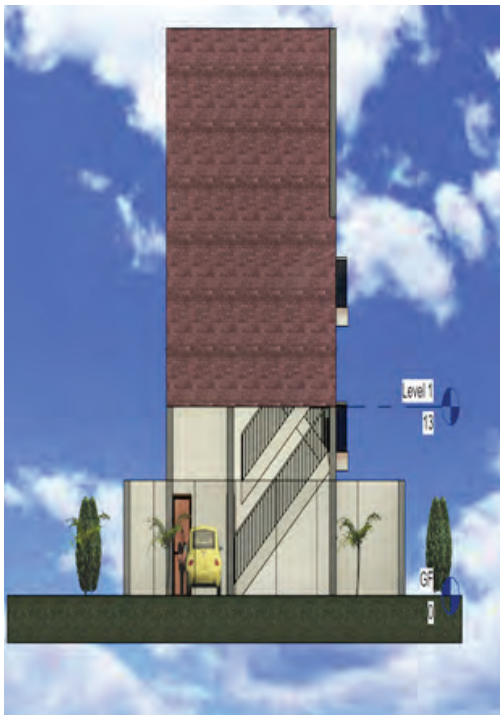


Fig. 5. Front View of Residential Building in Revit software

RESULTS AND DISCUSSION

The study concludes that Building Information Modeling (BIM) is a transformative technology that significantly enhances the design, planning, and construction of residential buildings. Unlike CAD, which is limited to drafting and basic modeling, BIM enables an integrated, data-rich environment where collaboration and real-time decision-making thrive. By improving visualization, coordination, and project control, BIM reduces errors and accelerates timelines.

Moreover, BIM aligns well with sustainable building practices by enabling accurate material estimation and lifecycle analysis. Although there are barriers to adoption, such as training requirements and software costs, the long-term benefits far outweigh these initial challenges. Residential construction firms that adopt BIM gain a competitive advantage by delivering higher quality projects more efficiently.

As the construction industry continues its digital transformation, BIM will likely become the standard

platform for design and construction management. It is essential for professionals in the field to embrace BIM tools and invest in developing the necessary skills for effective implementation.

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Experimental Investigation on Concrete as a Partial Replacement of Cement by Silpozz with Addition of Peg400

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ABSTRACT

Solid waste management is the main issue because of the growing amounts of waste materials and industrial byproducts. A variety of agricultural waste products are used in industry; for example, silpozz is a result of rice husk ash. This study aims to use alternative components in concrete in a beneficial way without sacrificing the needed strength. In this study, concrete of M30 grade was designed and utilised. Initially, standard mix concrete is made without replacing any silpozz (SP). The second series maintains Peg400 while varying silpozz by 5%, 10%, 15%, and 20%. Concrete mixes' workability, compressive, split tensile, and flexural strengths have all been established. According to the results, using silpozz in place of cement up to 15% increased the concrete's strength when compared to traditional concrete.

This study concludes that Silpozz with PEG400 can be a viable and eco-friendly partial replacement for cement in concrete.

KEYWORDS : SP (silpozz), Peg-400 (polyethylene glycol).

INTRODUCTION

Concrete: A composite material's primary constituents are embedded aggregate particles or fragments, usually a blend of fine and coarse aggregate, in a binding medium, like a Portland cement and water mixture. Concrete is the most versatile and commonly employed building material in the world.

Silpozz: Rice husk is burned in a furnace at a regulated temperature—below 7000 degrees Celsius—to produce silpozz. The resulting ash is known as amorphous silica since it is amorphous in form. Silpozz is the trade name for amorphous silica. With a silica content of over 90% and a particle size of 25 microns (micro silica), Silpozz is a super-pozzolana that may be utilized extensively to create unique cement and concrete. Silpozz comes in two colours: white and grey. Silpozz is a green product that is carbon neutral and may be used as a silica fume at a significantly reduced cost without sacrificing quality.

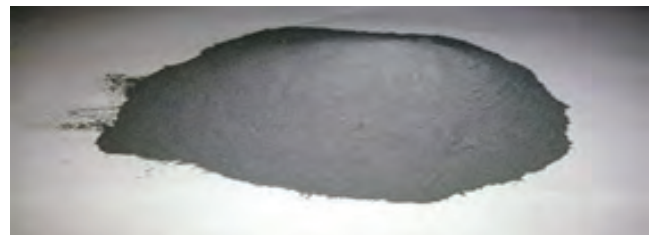


Fig. 1 : SILPOZZ(micro silica)

Admixture Peg400

The condensation polymer of ethylene oxide and water, known as PEG-400, has the general formula $H(OCH_2CH_2)_nOH$, where "n" is the average number of oxy-ethylene group repeats, usually ranging from 4 to roughly 180. The acronym "PEG" is an acronym for average molecular weight that is joined with a numeric supplement. One of PEG's many apparent benefits is that it dissolves in water. Because polyethylene glycol is non-toxic, odourless, neutral, lubricating, non-volatile,

and non-irritating, it is used in many pharmaceutical goods.



Fig. 2 : PEG400

LITERATURE REVIEW

1.Praveer Singh et al "THE EFFECT ON CONCRETE BY PARTIAL REPLACEMENT OF CEMENT BY SILICA FUME: A REVIEW " (Mar-2016) -This review research leads to the conclusion that compressive strength falls as workability increases. When silica fume is ideally substituted for cement at a rate of 5% to 15%, compressive strength increases; however, when silica fume replacement approaches 20%, compressive strength declines. Changes in the w/c ratio affect the compressive strength of concrete. As the w/c ratio increases, compressive strength declines, and vice versa. Concrete conditions and resistance to acidic water attacks are improved when silica fume is supplied in the proper amounts. Due to its great fineness, silica fume has a high normal consistency. The compressive strength of silica fume is higher than that of any other substance, including fly ash.

2.K.C. Panda and S.D. Prusty et: "Influence of silpozz and rice husk ash on enhancement of concrete strength" - The findings of a study that looked into combining silpozz and rice husk ash (RHA) to increase the strength of concrete are presented in this paper. In this investigation, 20% of the total amount of "supplementary cementitious material (SCM)" was substituted. Six concrete mixes were made, including one that had no silpozz and RHA added to the cement (0% silpozz and 0% RHA), which is considered conventional concrete. But in the other five concrete mixes—20 percent silpozz and 0% RHA, 5% silpozz and 15% RHA, 10% silpozz and 10% RHA, 15% silpozz and 5% RHA, and 0% silpozz and 20% RHA—20 percent silpozz and RHA were added

to the cement. The super plasticiser dosage was raised when the water-binder (w/b) ratio fell to 0.375, 0.325, and 0.275. A new generation polycarboxylate base water reduction admixture called Cera Hyperplast XR-W40 was employed in this study. The study's findings suggest that in order to improve concrete's workability when w/b drops, the dosage of super plasticiser must be raised. The impact of substituting silpozz and RHA for cement on the flexural, split tensile, and compressive strengths was assessed. For all w/b ratios, the concrete mixture containing a distinct combination of silpozz and RHA provides greater strength than the control specimen. Concrete's early strength is higher than its latter strength.

OBJECTIVE OF THE PROPOSED RESEARCH

- a) To study the properties of concrete adding PEG400 i.e. 1%
- b) To study the compressive strength, Flexural strength & Split tensile strength of concrete by varying silpozz content in concrete
- c) Compare the results of conventional concrete with silpozz.

METHODOLOGY

In this research the physical properties of materials are studied that involve cement,sand, coarse aggregate, and silpozz were tested individually.

Mix proportion is obtained by referring to IS10262-2009

Water, fine and coarse particles, and binding agents make up concrete. Knowing the properties of the materials utilized in the concrete, which involve bulk density, fineness modulus, bulk density, bulking, initial and final setting times, fineness, normal consistency, and specific gravity of fine and coarse aggregates, can be essential before starting this investigation.

Cement: Throughout the project, regular Portland cement (43 grade) of the Coromandel King brand, made from a single batch, will be utilised.

Table 1. Properties of cement

Sl. No	Properties	Results
i.	Specific gravity	3.1

ii.	Normal consistency	32%
iii.	Initial setting time	35min
iv.	Final setting time	480min

Fine Aggregate: Sand from locally accessible riverbeds that is free of organic matter and other harmful substances is used as the aggregate. It is made up of well-grade fine aggregate (shape sand) that passes a 4.75mm screen and is free of salt.

Table 2. Properties of Fine aggregate

Sl. No	Properties	Result
i.	Specific gravity	2.53
ii.	Bulk density (compacted condition)	1559.22 Kg/m ³
iii.	Bulk density (Loose condition)	1415 Kg/m ³
iv.	Fineness modulus	3.24 %

Coarse aggregate: In this investigation, 20mm crushed coarse aggregate and downsized rounded material from a nearby crusher facility are utilised.

Table 3. Properties of coarse aggregate

Sl. No	Properties	Result
i.	Specific gravity of C.A	2.79
ii.	Fineness modulus	8.57 %
iii.	Impact Strength	9.16 %

Silpozz

In the calculated ratio, it is utilised to partially replace cement.

Water

The investigation will employ portable water for curing and mixing.

Mix Proportions

M30 grade was employed to create five different combinations. The first proportions of the mix were conventional concrete (regular concrete), followed by PEG400 1% constant, which replaced 0%, 5%, 10%, 15%, and 20% of the silpozz. For 28 days of compressive, split tensile, and flexural strength, the mix proportions in the table meet Indian standard specification IS: 10262-2009.

Table 4. For Three Cube

Mix No.	Silpozz (%)	Cement	Coarse aggregate	Fine aggregate	Silpozz (gm)	PEG400 (ml)	Water (kg)
		KG					
M1	0	5.42	19.32	11.28	0	0	2.44
M2	5	5.15	19.32	11.28	270	48.18	2.44
M3	10	4.88	19.32	11.28	542	48.18	2.44
M4	15	4.61	19.32	11.28	813	48.18	2.44
M5	20	4.34	19.32	11.28	1084	48.18	2.44

Table 5. For Three prism

Mix No.	Silpozz (%)	Cement	Coarse aggregate	Fine aggregate	Silpozz (gm)	PEG400 (ml)	Water (kg)
		KG					
M1	0	7.89	21.09	12.24	0	0	3.55
M2	5	7.50	21.09	12.24	390	70.13	3.55
M3	10	7.10	21.09	12.24	790	70.13	3.55
M4	15	6.70	21.09	12.24	1180	70.13	3.55
M5	20	6.31	21.09	12.24	1580	70.13	3.55

Table 6. For Three Cylinder

Mix No.	Silpozz (%)	Cement	Coarse aggregate	Fine aggregate	Silpozz (gm)	PEG400 (ml)	Water (kg)
		KG					
M1	0	5.58	14.90	8.64	0	0	2.51
M2	5	5.30	14.90	8.64	280	49.6	2.51
M3	10	5.02	14.90	8.64	560	49.6	2.51
M4	15	4.74	14.90	8.64	840	49.6	2.51
M5	20	4.46	14.90	8.64	1120	49.6	2.51



Fig. 3. Casting of specimens



Fig. 4. Curing of specimens



Fig. 5. Testing of specimen

Flexural Strength Test:The flexural testing machine employed a total of 15 prism specimens measuring 150 x 500 mm. The test results have been listed in tables below, with each number representing the average of three test results.

Split tensile strength: Total of 15 cylinder specimens of size 150mmx300mm x 300 mm been employed for compression testing machine, the test results have been summarized in tables below. Every value is the mean of three test results.

Table 7. Compressive Strength of cube

SI	% of silpozz Added	Weight (Kg) 28 Days	Load of specimen (KN)	Compressive strength(N/mm ²)
1	0%	8,765	910.6	40.47
		8,530	912.1	40.53
		8,600	806.4	35.84
				38.94
2	5%	8,540	917	40.75
		8,416	860.2	38.23
		8,410	897.9	39.90
				39.62
3	10%	8,590	1100	48.88
		8,460	999.2	44.40
		8,474	885.1	39.33
				44.20
4	15%	8,510	990	44
		8,565	1102	48.97
		8,615	993.5	44.15
				45.70
5	20%	8,205	802	35.64
		8,545	795	39.77
		8,395	757	38.12
				37.84

EXPERIMENTAL INVESTIGATION

Preparation of test specimens

Slump tests were performed on each mix to evaluate its workability, concrete cubes (150 x 150 x 150mm) had been employed to determine compressive strength, and a cylinder (150mm in diameter and 300mm in depth) was utilized to determine split tensile (100 x 100 x 500mm) for flexural strength. The specimens were demolded after a 24-hour casting time and kept in moist gunny bags for the next 28 days. The specimens will undergo testing for flexural strength, split tensile strength, and compressive strength.

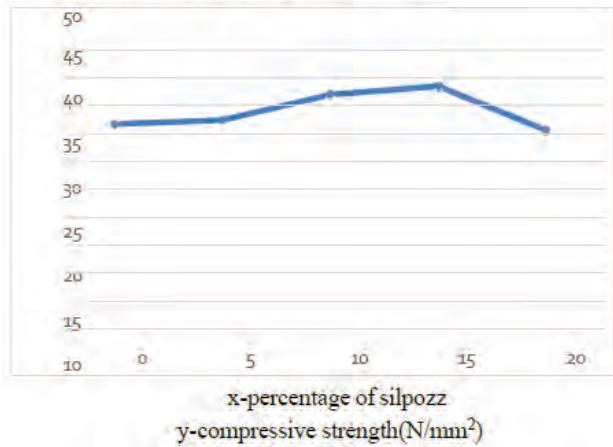
RESULTS AND DISCUSSION

Compressive strength: For the compression test, a total of 15 cube specimens measuring 150mm by 150mm were employed. The test outcomes are compiled in tables below, where each number represents the average of three test results.

Table 8. Flexural Strength of Prism

SI	%of silpozz Added	Weight (Kg) 28 Days	Load of specimen (KN)	Flexural strength(N/mm ²)	
1	0%	12.160	24	12	12.16
		12.390	24	12	
		12.610	25	12.5	
2	5%	12.250	26	13	12.66
		12.250	24	12	
		12.160	26	13	
3	10%	12.030	24	12	13.16
		12.360	25	12.5	
		12.740	30	15	
4	15%	12.930	31	15.5	14.33
		12.800	27	13.5	
		12.840	28	14	
5	20%	12.410	26	13	14.16
		12.530	29	14.5	
		12.710	30	15	

compressive strength Graph(cube)



Flexural strength Graph(prism)

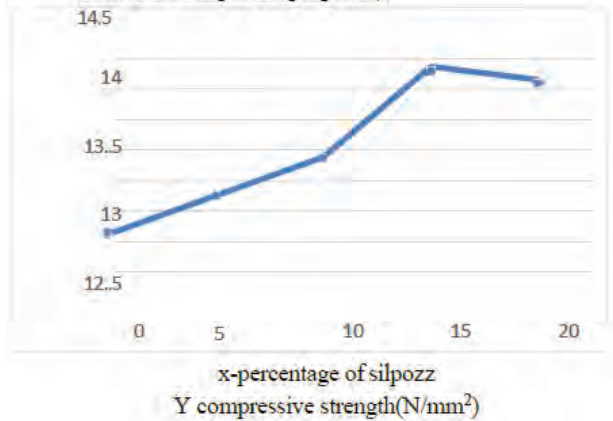
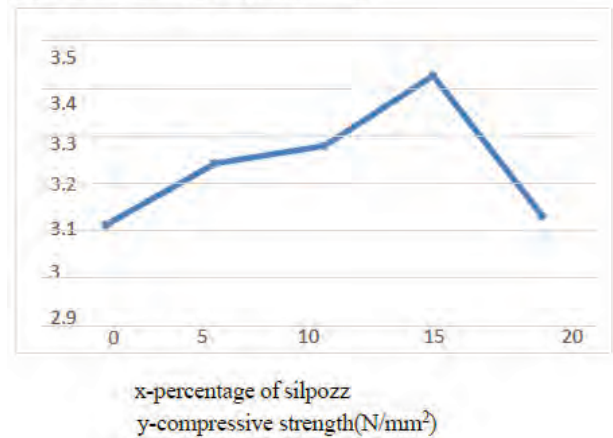


Table 9. Split tensile Strength of cylinder

SI	%of silpozz Added	Weight (Kg) 28 Days	Load of specimen (KN)	Compressive strength(N/mm ²)	
1	0%	13.115	257.1	3.63	3.12
		13.030	185.4	2.62	
		13.020	226	3.19	
2	5%	12.910	251.3	3.55	3.26
		12.250	210.6	2.97	
		12.300	228.18	3.23	
3	10%	12.940	268.9	3.80	3.30
		13.050	198.9	2.81	
		13.105	228	3.28	
4	15%	12.900	252.7	3.57	3.46
		12.925	238.12	3.36	
		12.992	244.9	3.47	
5	20%	12.920	230.9	3.26	3.14
		13.020	214.5	3.03	
		12.855	222.5	3.15	

Split tensile strength graph(cylinder)



CONCLUSION

- Conventional concrete has an average compressive strength of 38.94N/mm², flexural strength is 12.16 N/mm² & split tensile strength of 3.12 N/mm².

- Concrete with 15% silpozz and 1% PEG400 has an average compressive strength of 45.70N/mm² & conventional concrete is 38.94 N/mm². Percentage increase is 17.36%
- Concrete with 15% silpozz and 1% peg has an average flexural strength of 14.33N/mm² & conventional concrete is 12.16N/mm². Percentage increase is 13.73%
- Concrete with 15% silpozz and 1% PEG400 has an average split strength of 3.46N/mm² & conventional concrete is 3.12N/mm². Percentage increase is 10.89%.
- silpozz is substituted for regular cement & addition of 1% PEG400, the structure's lifespan is extended and its durability is increased.

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Experimental Studies on Wastewater as Mixing Water in Cement Mortar

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ABSTRACT

We all know that Water stands one of global valuable aids to humanity. It seems to be the most mutual liquid by the maximum usages of all liquids on the world. There fore even a single drop must not be misused and its time to use the water in systematic way. Construction industry needs lot of water for developing infrastructure throughout the world. hence, using of primary and secondary treated wastewater in construction activities has become necessary globally. Selecting and using of wastewater has become quit common in producing of concrete. The aim of this research is to identify the option of using treated waste water in construction industries as alternate to drinkable water by carrying all the tests to know better about the properties of concrete with treated waste water. For this research samples were collected from Dairy waste water (DWW), RO waste water and portable water (TW). The performance of Dairy wastewater and RO waste water on physical properties like setting time of cement, study is done on Hydration process of cement and strength characteristic on different grades of cement (OPC 53, OPC 43) and PPC. Laboratory Tests were carried out and the results were compared with reference specimens. Tap water is replaced with Dairy wastewater (DWW) and RO wastewater with varying percentage like 25%, 50%, 75% and 100% by its weight and compressive strengths is checked. Mortar cube made up with different grades of cement were casted for 07, 28days and 90days. The cement cubes were cured for a period of 07days, 28days. No much changes are detected in initial and final setting time. For 25 % and 50% replacement of waste water no substantial changes were detected for compressive strength and for 75 % and 100 % replacement of wastewater the compressive strength is reduced in all types of cement and water.

KEYWORDS : Dairy wastewater (DWW), RO wastewater, Tap water (TW), Cement OPC43, OPC53, PPC.

INTRODUCTION

At present-day, there is scarcity of data on quality of waste water which is suitable for using in concrete as a mixing water. The acceptable limits of water which is used for concrete mixing water are collected from the literature survey. Some of these constraints are reflected in existing regulations that permit the use of recycled water. Portable Water is the greatest common and crucial natural source that sustains life on human. Only 3% of the Earth's surface is thought to be fresh water; the rest 97% is made up of salt water found in the oceans. 2.4% of water is frozen in ice-bound caps, and the remaining 0.6% is found in groundwater lakes, rivers, and other bodies of water that are good for drinking. Concrete is

primarily composed of cement, aggregates, and water, making it a composite building material.

There are several elements that provide various qualities. The aggregate is often composed of coarse broken rocks and fine aggregate like river sand and M-sand. As a binder material cement is used i.e. pozzolana or Portland cement, and fly ash, GGBS and Silica fumes etc. are used as cementitious materials.

LITERATURE REVIEW

1. G. Reddy, Babu, and N. Venkata Rama (2018) In order to investigate the "Feasibility of wastewater as mixing water in cement," gathered data from fourteen water treatment facilities, each of which produces between 3500 liters and 4000 liters of

potable water per day and releases about 1,00,000 liters of wastewater per day into sewers. the effects of four wastewater treatment plants on physical characteristics such flexural strength, compressive strength, and setting times. The OPC three, seven, and twenty-eight days compressive strength findings. Flexural strength is equivalent to DW and XRD after three, seven, twenty-eight, or ninety days. Using reference materials, C3S, C2S, and Ca(OH)₂ were identified as crystalline compounds. They concluded that the test samples' compressive and flexural strengths were inferior to those of the reference samples.

2. Khushboo Meena et.al have "studied the effects of wastewater on the properties of concrete" For M25 grade concrete, three types of waste water are used: tertiary processed waste water, treatment waste water, and tapwater. By the percentage of water sample such as 0% and 100% for casting and curing of each sample of water. They have conducted various experimental such as Compressive strength, Flexural strength, carbonation depth, abrasion resistance test, chloride-ion concentration.
3. Shekhar Saxena et al have worked on "Impact of use of steel slag as coarse aggregate and wastewater on fresh and hardened properties of concrete". In this investigation, M25 grade concrete is manufactured by partially replacing the coarse aggregate with steel slag by 15%, 25%, 50%, 75% and 100% with the water as tap water and domestic wastewater for each percentages of slag. Adopted the various methodology by determining results such as Hardened density, Compressive force, bending strength, Elasticity of modulus (E), SEM, Rapid chloride permeability test and ultrasonic pulse velocity.

METHODOLOGY

Analysis was done on tap water and effluent from water treatment facilities. The amounts of fine aggregate, cement and water for each given specimen were 200 grammes, 600 grammes, and (P/4 + 3), where P is the proportion of water needed to produce a standard consistency. Five trials were prepared, and test were carried out for setting times by using Vicat’s apparatus.

Ninety cement mortar cubes were casted of dimension 70.6x70.6x70.6 mm in which forty-five mortar cubes were casted with DWW and forty five mortar cubes were casted with RO wastewater for compressive strengths. All these specimens were tested for a age of 7 days, 28 days and 90 days. For first 24 hours the specimens were kept under gunny bag curing and after 24-hrs all specimens were immersed in water for curing period of 27days and 90days.

Materials and Laboratory Testing Program

Cement

Ordinary Portland cement: OPC 43 grade, OPC 53 grade and Portland pozzolana cement (PPC) cement were used for the study

Fine Aggregate

The locally available fine aggregates conforming to IS383-1973 was used for the study.

Water

In the laboratory, a total of four mix combinations were created and tested. These four mixtures are made by substituting treated and untreated wastewater with tap water at percentages of 25%, 50%, 75%, and 100%.

Table 1. Chemical composition of waste water

SL. NO	Parameter	Tap Water	Dairy wastewater	RO wastewater	Permissible limit as per IS standards
1	colour	Colour less	White	White	colourless
2	odour	Odour less	putrid milk Odour	unobjectionable	unobjectionable
3	BOD(mg/l)	Nil	25	20.3	-----
4	COD mg/L	Nil	16296	6700	-----
5	pH value	8.12	12.36	11.55	7.0-8.5
6	Nitrate Nitrogen (NO ₃ ⁻ N) mg/L	8.47	84.15	127.63	45-100
7	Total dissolved Solids (mg/l)	363	1862	2029	2000
8	Suspended Solids mg/L	104	2351	1870	<2000
9	Total Alkalinity as calcium carbonate, mg/L	163.56	516.52	590.73	200-600
10	Chlorides (mg/l)	478.12	1764.45	1650.36	2000
11	Sulphate as SO ₄ mg/L	45.01	382.35	375.41	200-400
12	BOD ₅	0	210.78	351.58	100
13	Turbidity, NTU, Max	0.15	3.61	3.45	5
14	Total Hardness(mg/l)	138.15	268.89	354.36	200-600

Powdered X-Ray Diffraction (XRD)

Investigation for crystalline compounds were done by using powdered XRD technique. This technique is used to check the hydration of cement.

Scanning Electron Microscopy (SEM)

Void structure is a critical micro structure property of cement mortar. since it determines physical and mechanical qualities as well as durability. SEM images of cement mortar samples mixed with DWW and RO water over a curing duration of 28 days.

RESULTS, AND DISCUSSION



Sl NO	DESIGNATION	COMPRESSIVE STRENGTH WITH RO WASTEWATER (N/mm ²)								
		PPC			OPC 43			OPC 53		
		7	28	90	7	28	90	7	28	90
1	MC00	22.5	36.51	45.34	25.5	45.34	48.34	35.15	46.7	62.28
2	MC25	21.6	34.91	43.74	22.6	44.73	45.5	29.6	45.16	60.2
3	MC50	23.1	41.73	44.15	23.1	44.14	45.35	28.15	42.2	60.54
4	MC75	20.16	33.51	41.13	18.16	30.12	40.65	25.25	31.38	46.8
5	MC100	18.5	32.3	39.32	18.7	28.32	38.75	22.8	30.2	42.2

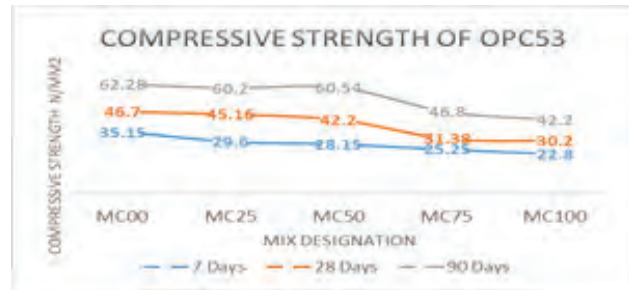
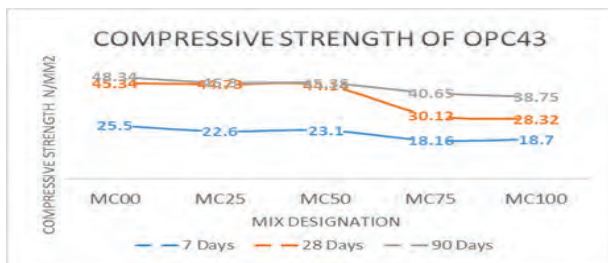
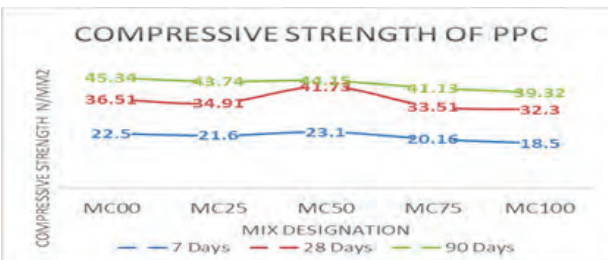


Fig. 3: Graph of compressive strength of cement mortar

From the figure no 3 its clearly observed that with the use of all three grade of cement i.e OPC43, OPC53 and PPC the compressive strength is varied for every replacement level of wastewater. The cubes casted with PPC cement upto 50% replacement of wastewater there is no much variation in compressive strength but for 75% and 100% replacement the strength has been reduced for all the age groups 7, 28 and 90 days by varying percentage of 75% replacement -10.4 %, -8.21% and -9.28% and for 100% replacement 17.77%, 11.53% and 13.27% respectively. The permissible limit for suspended particles in water is fewer than 2000 mg/liter according to IS regulation IS:456-2000. Because of increase in suspended particles and chloride content the results are decreased because increase in wastewater which contents solid particles like dissolved solids and suspended solids which impacts the strength characteristics. And also strength and durability is effected by high content of chlorides in water salt content, high alkali chloride(Cl₂) and sulphates(SO₃).

Similarly for OPC43 and OPC53 grade cement the compressive strength results are reduced for 75% and 100% replacement of wastewater. Upto 50% replacement the results are showing within the boundaries as per code IS: 456 – 2000.

Table 3. Compressive Strength of Cement with DWW Water

Sl NO	DESIGNATION	COMPRESSIVE STRENGTH WITH DWW (N/mm ²)								
		PPC			OPC 43			OPC 53		
		7	28	90	7	28	90	7	28	90
1	MC00	20.5	35.5	44.9	23.15	46.3	47.5	40.15	56.9	63.3
2	MC25	19.1	35.2	41.3	21.85	46.9	47.1	39.25	54.2	61.5
3	MC50	18.5	33.3	40.6	23.1	43.5	45.9	38.8	53.1	60.6
4	MC75	18.85	26.9	28.1	18.16	32.6	38.2	32.56	41.1	44.3
5	MC100	16.8	24.5	28.7	18.7	31.3	32.7	30.89	38.2	40.9

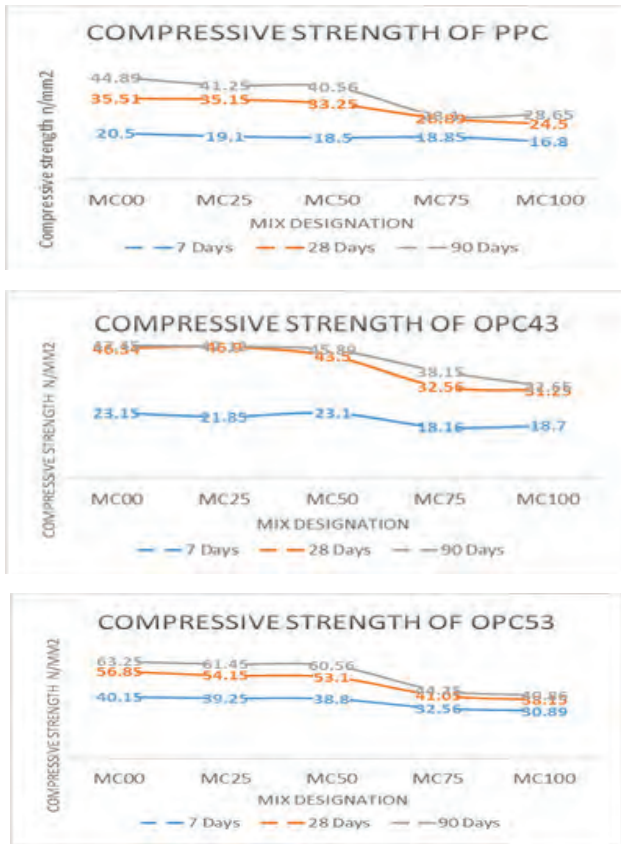


Fig. 4. Graph of compressive strength of cement mortar

From figure 4 its absorbed that for replacement of wastewater 25% and 50% the compressive strength have shown good results and for 75% and 100% replacement decreased as compared with 25% and 50% replacement of wastewater. Earlier compressive strength is decreased for the curing age of 7days, 28days and 90days. But later on as age period is increased the compressive strength is increased for both 25% and 50% replacement of wastewater respectively.

Test on Cement by SEM and XRD analysis

SEM-Scanning, Electron, Microscopy-DWW

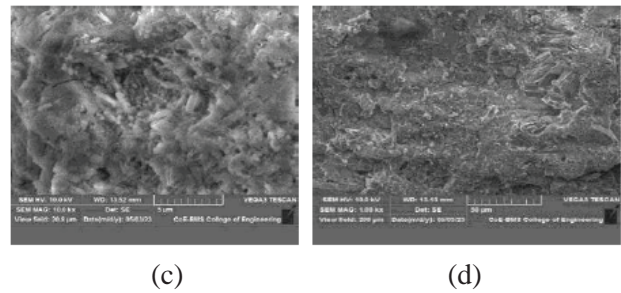
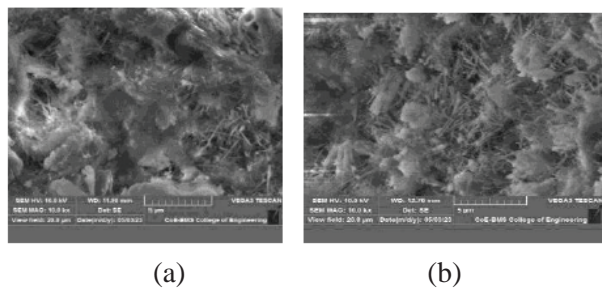


Fig. 5. SEM image of cement mortar samples (A) 53DWW25, (B) 53DWW50, (C) 53DWW75, and (D) 53DWW100

The specimen casted with DWW wastewater and analysed for SEM are shown in figure no-5. The SEM results are depicted by four images, namely A, B, C, and D, showcasing different levels of percentage replacement: 25%, 50%, 75%, and 100%. In images A and B, we can perceive the presence of needle-like and crystal-like structures. It indicates that hydration of cement process has taken properly, less amount of voids and faults are found, SEM micrographs of mortar samples that included 100% wastewater revealed holes. On the other hand, in the sample micrographs with 75% and 100% replacement (depicted in images C and D), numerous voids and holes are visible.

SEM-Scanning, Electron, Microscopy, with-RO

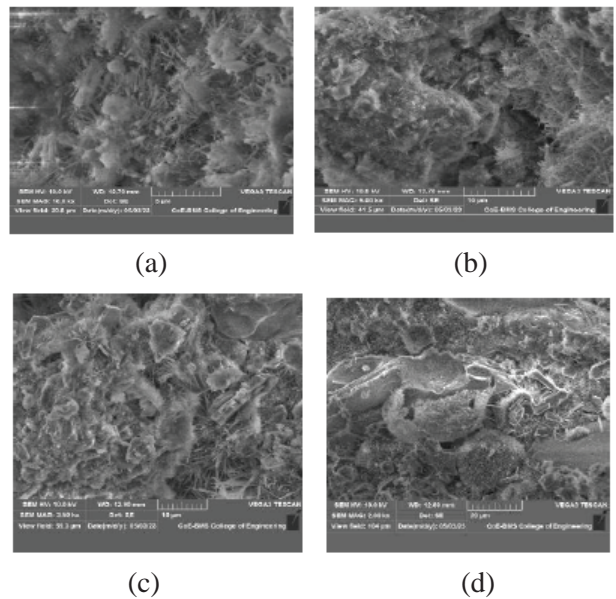


Fig. 6. SEM image of cement mortar samples (A) 53RO25, (B) 53RO50, (C) 53DRO75, and (D) 53RO100

The specimen casted with RO wastewater and analysed for SEM are shown in figure no-6. The SEM results are depicted by four images, namely A, B, C, and D, showcasing different levels of percentage replacement: 25%, 50%, 75%, and 100%.

The XRD analysis of the mortar sample containing a 50% combination of DWW and RO indicated the presence of key mineral components, including Calcium (Ca), Magnesium (Mg), Silicon (Si), Aluminum (Al), Iron (Fe), and Sodium (Na). Calcium silicate aluminate hydrate (C(-A)-S-H) was identified as the primary hydration product used in cement-based materials. This compound plays a vital role in influencing the mechanical properties and volumetric deformation of the cement matrix. Figure No-7 Graph of XRD Results with Oxides

SEM images were obtained for mortar specimens that had been cured for 28 days. These images revealed the presence of various compounds, including Aft (ettringite), Afm (monosulfur hydrated calcium sulphoaluminate), C-S-H (calcium silicate hydrate), CH (calcium hydroxide), and CC (calcium carbonate). EDS was employed to conduct additional analysis on the generated products in the mortar specimens, in addition to SEM. From Figure 6 and Figure 7 illustrate the essential chemical constituents of the mortar, including C, O, Ca, Si, Al, Mg, and S. The XRD examination uncovered the presence of needle-shaped or rod-shaped particles such as Aft crystals. As the fraction of wastewater used to replace filtered water increases, the abundance of rod-like or needle-like Aft particles decreases, while honeycomb or cluster-like particles become more prominent, as depicted in image D. This may be the result of specific pores in mortar specimen enabling Aft to form (Aft produces enlargement stress). Mortar sample develops cracks and pores when the expansion stress higher than the tensile stress, which reduces the mortar compressive strength

CONCLUSION

1. OPC53 grade cement has exhibited favorable performance in terms of setting time when compared

to OPC43 and PPC cement. The utilization of RO and DWW as partial water replacements has resulted in a gradual reduction in the setting time of the cement, as indicated by the test results.

2. Due to the addition of RO wastewater (25%,50%,75%, and 100%) with OPC43, OPC53 and PPC cement, the compressive strength of cement mortar has shown optimum results for OPC53 grade cement.
3. The compressive strength of RO and DWW test sample were low then that of controlled sample within the boundaries as per code IS: 456 – 2000.
4. The chlorides content from wastewater can damage reinforcing steel if they are present in concrete, thereby decreasing the building's,

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3D Visualization of Residential Building

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ABSTRACT

In this project we developed a comprehensive 3D visualization project using SketchUp Pro, demonstrating an impressive blend of technical skill and creative design. The project, part of a student competition, showcases the complete modeling of a residential building—a from concept to presentation—utilizing cutting-edge tools and workflows. The project began with site selection and analysis, where the team studied terrain, climate, sunlight, and local zoning regulations. Using SketchUp's geo-location and shadow tools, they created a digital site model that informed building orientation and environmental responsiveness. In the conceptual phase, floor plans and spatial layouts were developed, ensuring functional zoning and natural light optimization. The model was built using SketchUp's native tools like Push/Pull, Follow Me, and Solid Tools, while extensions like V-Ray, Skatter, and FredoTools enhanced rendering and detailing. The architectural modeling process was divided into structured phases: structural modeling, interior design, exterior landscaping, and furnishing. Each component was grouped and tagged for efficient organization. The team used the 3D Warehouse for furniture and fixtures, and applied realistic materials and textures to bring the design to life. For visual presentation, the students rendered photo realistic images and created a walk through animation using V-Ray, highlighting the spatial flow and ambiance of both interiors and exteriors. SketchUp's Layout tool was employed to generate professional floor plans, sections, and elevations with annotations. This project not only reflects technical accuracy and aesthetic depth but serves as a model for architecture students learning digital design tools. It underscores the power of 3D modeling in modern architecture—bridging conceptual ideas with visual storytelling—and stands out as a showcase of what can be achieved through skilled use of software, planning, and design thinking.

KEYWORDS : Dairy wastewater (DWW), RO wastewater, Tap water (TW), Cement OPC43, OPC53, PPC.

INTRODUCTION

Sketchup Developed for the conceptual stages of design, SketchUp is powerful yet easy-to learn 3D software. We think of it as the pencil of digital design. This award-winning software combines a simple, yet robust tool-set that streamlines and simplifies 3D a design inside your computer. SketchUp is being used by anyone with the desire to Dream, Design and Communicate in 3D! From the entire SketchUp team,

thank you for trying SketchUp, and welcome to the SketchUp user community.

LITERATURE REVIEW

Enes Yigitbas, Alexander Nowosad & Gregor Engels (2023): Systematically reviews studies combining BIM with AR/VR for building design/construction/operation. Analyses 32 papers (from 2017–2022), categorizes by lifecycle phase (design, construction, operation), and identifies use-cases: VR for design review and AR for

construction/operation. Shows growing prominence of immersive visualization in AEC.

Rafał Stabryła & Magdalena Grudzińska (2025): Pilot empirical study on 10 single-family houses using BIM + mobile-VR. Finds that immersive VR significantly improves spatial understanding (layout, proportions), user engagement, and supports design decision-making. Demonstrates that even low-cost, smartphone-based VR is viable for residential clients — widening accessibility.

Reza Zaker & Eloi Coloma 2018: Demonstrates a real-world workflow where BIM models (with MEP, architecture, structure data) are exported to a VR environment for collaborative design review. Shows benefits: immersive visualization improves stakeholder understanding, coordination, clash detection; helps overcome limitations of traditional 2D/plan-based reviews.

OBJECTIVES

This project utilizes SketchUp Pro to develop a comprehensive 3D model that accurately represents the proposed architectural design. The primary objective is to create a detailed, scaled, and visually accurate representation of the structure, including floor plans, elevations, and spatial layouts.

METHODOLOGY

The methodology for this project outlines the step-by-step process undertaken to create a comprehensive 3D visualization of a residential building using SketchUp. In architectural design and planning, visualization allows for better understanding, modification, and communication of ideas before construction begins. This methodology integrates practical modeling techniques with theoretical design planning, emphasizing both technical accuracy and aesthetic presentation.

SketchUp is chosen for its user-friendly interface, efficient modeling capabilities, and wide compatibility with third-party extensions like V-Ray and Enscape. The entire modeling process is structured into sequential phases: data collection, conceptual planning, software preparation, modeling, detailing, rendering, and presentation. Each phase contributes to the accuracy and realism of the final output.

Data Collection and Site Analysis

The first phase of the project involved gathering relevant site information and design requirements. This included architectural floor plans, elevations, and sectional drawings of the proposed residential building. If such drawings were unavailable, measurements were taken manually from a hypothetical or provided site layout.

The analysis considered the plot dimensions, orientation (north direction), surrounding structures, and climate-related factors such as sunlight direction and prevailing wind flow. Understanding these elements was essential to developing a design that is both functional and contextually responsive. Building codes and zoning regulations were reviewed to ensure the design conformed to local standards regarding height restrictions, building setbacks, and permissible construction area.

The data collected was then organized into usable references for the modeling process. This helped to establish a clear foundation for the 3D model and minimized errors during the modeling stage.

Conceptual and Spatial Planning

Once the data was collected and analyzed, the next step was conceptual and spatial planning. This involved determining the arrangement of functional zones within the residential building, including bedrooms, living areas, bathrooms, kitchens, staircases, and corridors. Sketches and bubble diagrams were used to conceptualize spatial relationships and circulation patterns.

This conceptual phase played a key role in ensuring that the design would meet user requirements while maintaining architectural integrity. Decisions regarding the number of floors, room sizes, and orientation were finalized during this stage.

The spatial plan was translated into a 2D layout using either CAD software or directly within SketchUp. This base plan was then used as a reference for the 3D modeling process. The focus was on optimizing space usage while considering natural light, privacy, and movement flow throughout the residence.

Software Setup and Tool Familiarization

With the design plan ready, SketchUp was installed and configured. The version used for this project was SketchUp Pro 2022, which includes advanced features such as solid tools, tag management, and rendering extensions. The modeling workspace was customized by adjusting unit measurements, importing templates, and organizing toolbars for efficient workflow.

A brief familiarization with SketchUp tools was carried out. Key tools such as:

- Line Tool (for creating edges and guides),
- Push/Pull Tool (for extruding surfaces into 3D volumes),
- Follow Me Tool (for complex profiles and shapes),
- Offset Tool (for creating parallel lines and shapes),
- Tape Measure Tool (for scaling and alignment),

Component and Group tools were also explored to help manage elements like windows, doors, and furniture more effectively. Plugins such as V-Ray (for rendering) and CleanUp3 (for model optimization) were installed and tested.

Base 3D Modeling

The modeling phase began with the creation of the base structure using the prepared 2D plan. The floor plan was either imported from a DWG file or recreated directly in SketchUp. Walls were extruded using the Push/Pull tool to a standard height (e.g., 3 meters per floor). Openings for doors and windows were cut out using the Rectangle and Push/Pull tools.

Each structural element was made into a group or component to allow easy editing and minimize geometry errors. Floor slabs, ceilings, and columns were added, ensuring that all architectural dimensions aligned with the design plan. Staircases were constructed using a combination of Push/Pull and Move tools, while the roof structure was created using the Follow Me and Rotate tools.

This base model served as the structural skeleton upon which detailed features were later added.

Architectural Detailing

After the basic structure was completed, attention was turned to architectural detailing. This included the addition of windows, doors, balconies, and façade elements. Pre-made components from the SketchUp 3D Warehouse were used where appropriate, especially for repetitive features like identical windows and standard doors.

Balustrades, roofing tiles, pergolas, and overhangs were modeled using both SketchUp native tools and downloadable assets. Care was taken to ensure all detailing aligned with the original design intent. Detailing not only enhanced the realism of the model but also allowed for better spatial understanding of the final design.

Grouping and tagging were consistently applied to keep the model organized, allowing different layers (e.g., structure, furniture, landscape) to be hidden or shown as needed.

Interior Design and Furnishing

The next phase focused on interior modeling and furnishing. Interior walls were detailed with materials such as plaster, paint, tiles, or wood finishes. Floor coverings—such as tiles, wood panels, and carpets—were applied using the Paint Bucket tool and texture editor.

Furniture and appliances were placed in their respective rooms to create a complete living environment. These included beds, sofas, kitchen counters, wardrobes, tables, chairs, lighting fixtures, and decorative items. Most elements were sourced from SketchUp's 3D Warehouse, while some were modeled from scratch for customization.

Interior lighting was considered both in terms of fixture placement and natural light penetration through windows and doors. The model aimed to balance functionality with visual appeal, giving a realistic impression of space usage.

Exterior Design and Landscaping

To contextualize the building, external features such as terrain, walkways, garden spaces, and driveways were added. The SketchUp Sandbox tool was used to create terrain surfaces based on the site topography. Grass textures, trees, shrubs, and flower beds were inserted

using the 3D Warehouse or specialized landscape plugins.

Paving stones, fences, external lighting, and boundary walls were modeled to define the plot and enhance realism. Elements like outdoor seating areas and pergolas were added to demonstrate how the exterior could be used for recreation or utility.

This phase contributed to giving the model a complete, real-world appearance that reflects the intended residential setting.

Rendering and Visualization

To enhance the visual quality of the model, the project incorporated rendering using V-Ray for SketchUp. This involved setting up cameras for interior and exterior scenes, configuring sun and artificial light sources, and applying realistic material properties such as reflectivity, bump maps, and transparency.

Lighting was adjusted to simulate different times of day, such as morning and evening sunlight. Rendering settings were fine-tuned for resolution, shadows, and ambient occlusion to achieve photorealistic output. Multiple high-quality images were produced, showcasing various parts of the building.

In addition to still renders, an animation walkthrough was created using SketchUp scenes and exported as a video to provide a dynamic representation of the design.

Review, Revisions, and Presentation

The final stage involved a comprehensive review of the 3D model. Any geometry errors, material mismatches, or missing elements were corrected. The model was evaluated based on its accuracy to the original design, visual clarity, and functionality.

Selected views were exported in JPEG and PDF formats for documentation. A project presentation was created, including:

Rendered images,

Floor plans and elevations,

Annotated views of interiors and exteriors,

A video walkthrough.

These deliverables formed the final output of the 3D visualization process and were used to present the design effectively to peers, instructors, or clients.

CONCLUSION

The study concludes that Sketchup can generate a program quickly, it is flexible to amend a program and has convenience multi-angle expression, and these demonstrate that it is designed to meet the design process and developed.

Based on studies and experiments that have been carried out, the final results regarding the performance of digital applications SketchUp and Enscape have the advantages of being easy to use, simple and attractive to use, speeding up the work, and realistic final drawings made it helpful for design simulation. Images can be exported to various application formats, drawings can be saved automatically with the automatic storage feature, and with many features can help architects and designers to improve the performance of design presentations. Besides having the advantages of digital applications, Sketchup and Enscape certainly have the drawbacks include that the drawings and lines are stiff, and it is difficult to make advanced modeling.

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Study on Strength Characteristic of Recycled Concrete Aggregate with Admixture

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ABSTRACT

The globe has begun to face significant challenges related to concrete engineering particularly because concrete has emerged as most utilized building material worldwide. Recycled aggregates (RA) are considered sustainable alternatives to natural aggregates (NA) in concrete, although their mechanical performance often falls short compared to NA. Partial replacement of NA with RA has garnered significant research interest in recent years. In this study, Various weight percentages of RA were combined with supplementary cementitious materials, like Ground Granulated Blast Furnace Slag (GGBS), fly ash (FA), silica fume, to produce conventional concrete. The concrete mix was planned to achieve target mean compressive strength of 31.5MPa as well as split tensile strength of 3.5MPa. Natural aggregates were substituted with recycled concrete aggregates at varying proportions of 0%, 15%, 30%, 45%, 60% by weight. The research examined how different combinations of recycled aggregates (RA), fly ash (FA), and GGBS influence the compressive behavior of concrete. Findings indicated that mixes containing 60% RA showed a noticeable drop in compressive strength after 7 and 28 days of curing. In contrast, blend incorporating 20% FA and 45% RA achieved higher compressive and split tensile strengths than other mixes utilizing FA. Meanwhile, the mixture with 20% FA and 60% RA exhibited around a 5% decrease in both compressive and split tensile strength compared with other GGBS-based combinations. Likewise, concrete incorporating 20% GGBS with 60% RA showed approximately a 4% strength reduction relative to other GGBS mixes.

KEYWORDS : *Recycled aggregates, Flyash, Split Tensile strength, GGBS, Compression strength, SEM analysis.*

INTRODUCTION

OPC concrete is broadly utilized material in construction of structures & lots and other similar types of infrastructure. When adequately designed and constructed, these structures provide years of service with little or no maintenance needs. The concrete industry is currently facing an acute shortage of natural aggregates. This has led many researchers and industries to find an alternative material replacing coarse and fine aggregate. Construction demolition generates approximately 150 million tonnes of waste annually in India. Due to poor waste management techniques and the least number of recycling plants, it manages to recover and recycle only about 1% of its waste generation, and the rest remains in landfills. Nevertheless, cement manufacturing poses

environmental challenges, including a significant carbon footprint, high energy consumption, and exhausting of natural resources. Carbon dioxide (CO₂) emissions from the manufacturing of concrete can be significantly decreased by “industrial by-products such as GGBS, fly ash, and construction and demolition (C&D) waste as supplemental or alternative cementitious materials (ACMs). Integrating ACMs like fly ash and GGBS” into concrete mixtures lowers the overall environmental burden while utilizing their pozzolanic characteristics, which play a vital role in long-term strength development. However, the incorporation of these ACM in the construction sector for producing concrete is a complex phenomenon. In concrete technology, significant research and development activities

have to be made on factors affecting the engineering characteristics of C&D aggregate concrete mixes and industrial by-product utilization.

LITERATURE SURVEY

H. Dilbas, M. Simsek, Ö. Çakır . The research employs demolished-building-rubble as recycled aggregate (RA) in concrete compositions, both with and without SF. Mechanical properties, including tensile splitting strength, compressive strength, and elasticity modulus, as well as physical properties, including density and water absorption ratio, have been assessed for concrete specimens. 30% of RA is suggested as optimal ratio for concrete mixtures. The 5% SF content in RAC is more feasible for enhancing low properties of the RAC, like compressive strength.

Dhiyaa “Mohammed, Sameh Tobeia, Faris Mohammed, and Sarah Hasan. Through trials, impact of” using recycled aggregate on concrete's compressive strength has been investigated. For improving strength of concrete containing RA, silica fume was also added as an admixture. Proportion of recycled aggregate varied from 0 to 100%, although silica fume content ranged from 0 to 10%. Findings demonstrated that recycled aggregate content raised, average compressive strength of concrete dropped significantly, from 30.85 MPa with 0% recycled aggregate to 17.58 MPa at 100%. Though adding silica fume improved strength considerably, raising it to 29.2 MPa even when concrete was made entirely with recycled aggregate.

OBJECTIVES OF THE STUDY

To “evaluate the strength of concrete by partial replacement of coarse aggregate with recycled concrete aggregate.

To ascertain the proportion of recycled concrete aggregate that can be substituted without compromising the concrete's strength.

To evaluate the strength of concrete by partial replacement of coarse aggregate with recycled concrete aggregate” by adding (ACM's) Fly ash & GGBS by replacing cement in different percentages to achieve target mean strength.

MATERIALS AND LABORATORY TESTING PROGRAM

Coarse aggregate

In this study, both recycled aggregates (RA) and natural aggregates (NA) were utilized. The RA was sourced from a demolished Grade-25 concrete structure, while the NA was obtained locally. The NA was crushed to a size of 20 mm. Previous research indicates that “well-graded aggregate distribution with nominal maximum size of” 20mm provides favorable characteristics for concrete production when using either RA or NA. In order to achieve high-strength concrete, 16, size distribution, and aggregate sizes are significant influencing factors. In this investigation, NA sizes that were within the grading limits specified by BS 882 (1992) and ranged from 10 to 20 mm were used. To separate the sizes, RA is subjected to sieve analysis. Prior to being used in blending, the RA and NA used in current study have been both saturated and dry. Regular stream sand, ranging in size from 0.075 - 1.18mm, was utilized as fine aggregate in each blend. When mixing, “dry surface-saturated state of sand is taken into account.

Table 1: Physical properties of NA, RA, and” fine aggregates

“Aggre-gate	Specific Gravity (kg/m3)	Bulk density (Kg/m3)	Water Absorption (%)	Fineness modulus
Natural aggregate	2.80	1.70	1.01	5.94
Recycled aggregate	2.60	1.70	4.3	6.16
Fine aggregate	2.50	1.53	1.01	5.94”

Methodology

As presented in Table 2, fifteen different mix combinations were formulated using various proportions of fly ash (FA), natural aggregates (NA), recycled aggregates (RA), and GGBS. The control mixtures consisted of five series with replacement “levels of 0%, 15%, 30%, 45%, and 60% by” weight. RA has been used in place of NA in these mixes, which were designated M1, M2, M3, M4, and M5. Different ratios of FA, GGBS, NA, and RA were included in the remaining 10 mixtures. For every mix in the

experimental program, three specimens were made. Ninety cubes with dimensions of 150×150×150mm and ninety cylinders “with dimensions of 150mm in diameter and 300 mm in height” were cast. Before mixing, RA was soaked in water for six hours, then surface-dried with a cloth before use. The wet concrete mixture was prepared by blending cement and binder materials (including silica fume) with RA and NA for approximately five minutes, with water added gradually. After that, the freshly mixed concrete was placed into moulds and kept alone for “a day. All specimens were cured under moist circumstances for the specified testing age following demoulding. Tests of compressive strength were conducted at 7 and 28” days.

Table 2: Mix-proportions of different mix trials

“Sample code	RA & Admixtures wt. %
M-1	0% RA
M-2	15% RA
M-3	30 % RA
M-4	45% RA
M-5	60% RA
“M-6	0% RA” + 10% FA
M-7	45% RA + 10% FA
M-8	45% RA + 15 % FA
M-9	45% RA + 20% FA
M-10	60% RA + 20% FA”
M-11	0% RA + 10% GGBS
M-12	45% RA + 10% GGBS
M-13	45% RA + 15 % GGBS
M-14	45% RA + 20% GGBS
M-15	60% RA + 20% GGBS

RESULTS AND DISCUSSIONS

When natural coarse “aggregates (NA) in concrete are partially or fully replaced with recycled aggregates” (RA), a reduction in compressive strength is generally observed. Figure 1 presents the influence of different RAC mixtures on compressive strength. As shown, the mix containing 100% natural aggregate exhibits the highest strength compared with all RAC mixes. In addition, compressive strength of the 100% NA mix increases by approximately 9.54% from 7 to 28 days, which aligns with trends reported by other studies

[17]. The compressive strength reaches its maximum when RA constitutes about 45% of the total coarse aggregates. However, when RA content exceeds 45%, compressive strength begins to decline. [18]. Based on these results, a replacement level of around 45% RA can be considered suitable for meeting engineering performance requirement

Compressive Strength of Concrete

Compressive Strength of Concrete with Varying Percentage of Recycled Aggregate & ACM’s

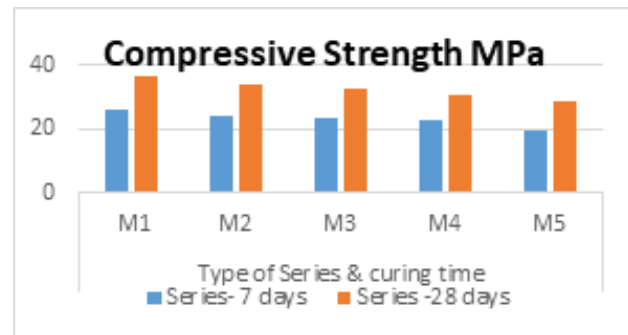


Fig. 1: Compression strength of M1-M5 specimen groups for 7- and 28-days curing

Figure 1 represents compressive strength results for mixes containing 100% natural aggregates (NA) and those incorporating 15%, 30%, 45%, and 60% recycled aggregates (RA). A “gradual reduction in compressive strength is observed as RA” content increases. For both 7-day and 28-day curing periods, the mix with 100% NA (M-1) exhibits higher compressive strength compared with all RA-based mixtures. The mixes “M-2, M-3, M-4, as well M-5 show progressive reductions in strength” corresponding to RA replacement levels of 15%, 30%, 45%, and 60%, respectively. When NA is replaced with RA, the overall density of the concrete decreases. The presence of adhered mortar on RA is a major contributor to this reduction, as it lowers the aggregate quality and subsequently weakens the concrete matrix strength.

Fly ash's impact “on compressive strength of concrete mixes with 100% natural aggregates” (NA) as well as those with 45% recycled aggregates (RA) is depicted in Figure 2. Fly ash is a useful additive that can increase strength of concrete. The mix containing 10% fly ash and 100% NA (M-6) achieves higher compressive

strength than the corresponding RA-based mixes at both 7 and 28 days. Among the mixes incorporating RA, M-9 demonstrates the highest compressive strength when 20% fly ash is combined with 45% RA, outperforming M-7, M-8, and M-10. While replacing NA with RA typically reduces concrete density due to attached mortar, the inclusion of fly ash improves the bonding within the matrix and enhances the performance of RA (21). Based on the observed results, incorporating 20% fly ash appears to be most effective proportion for improving strength characteristics of concrete containing recycled aggregates.

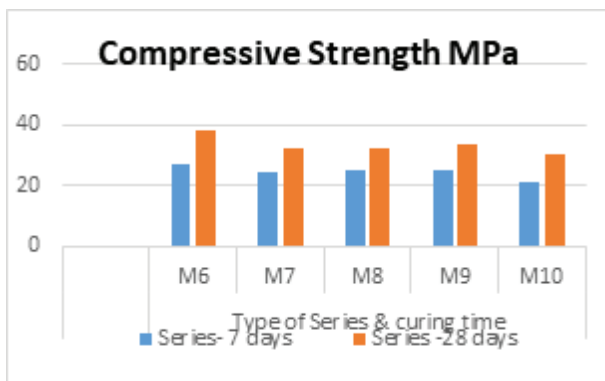


Fig. 2: Compression strength of M6-M10 specimen groups for 7- and 28-days curing

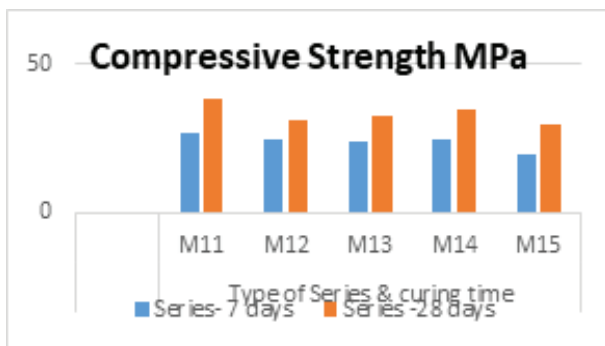


Fig. 3: Compression strength of M11-M15 specimen groups for 7- and 28-day curing

Figure 3 presents effect of incorporating GGBS on compressive “strength of concrete” mixes containing 100% natural aggregates (NA) and those with 45% recycled aggregates (RA). GGBS acts as an effective supplementary binder capable of enhancing the strength of concrete. The mix containing 10% GGBS and 100% NA (M-11) shows higher compressive strength than all RA-based mixes at both 7 and 28 days. Among the

RAC mixtures, M-14—containing 20% GGBS and 45% RA—achieves the highest compressive strength, outperforming mixes M-12, M-13, and M-15. Although substituting NA with RA generally lowers concrete density because of adhered mortar, the inclusion of GGBS enhances the bonding and mechanical performance of RA within the cementitious matrix (21). Based on the results, using 20% GGBS provides the most significant improvement “in the compressive strength of concrete containing recycled” aggregates.

Split Tensile Strength of Concrete with Different Percentage of Recycled Aggregate & ACM’s

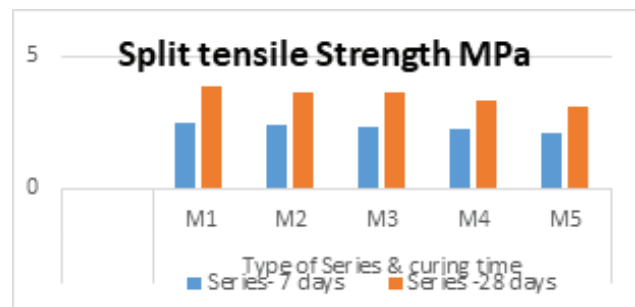


Fig. 4: Split tensile strength of M1-M5 specimen groups for 7- and 28-days curing

Figure 4 illustrates the effect on concrete's split tensile strength of substituting recycled aggregates (RA) in various ratios for natural aggregates (NA). The findings indicate that when the RA level rises, the tensile strength steadily decreases. This decline is mainly attributed to defects present in recycled aggregates and the relatively softer adhered mortar on their surface, which weakens the bond among RA particles and cementitious matrix. As a result, the strength loss becomes more pronounced at higher replacement levels. The “mixes M-1, M-2, and” M-3 achieve split tensile strengths that exceed the target value, whereas M-4 and M-5 exhibit reductions of approximately 3% and 10%, respectively. Overall, the split tensile strength improves with curing age due to increased binder activity and reduced pore volume within the concrete matrix.

Figure 5 shows influence of incorporating fly ash (FA) into mixes containing 0% RA and 45% RA on split “tensile strength of concrete. The mixes M-6, M-7, M-8, and M-9” exhibit split tensile strengths that exceed the target value, while the M-10 mix records reduction of around 5% compared to the target strength. Previous

studies (22) also reported that inclusion of fly ash improves mechanical properties of recycled aggregate concrete. Considering both strength enhancement and cost efficiency, replacing 10% of cement with fly ash appears to be most effective approach for achieving improved compressive as well as split tensile strengths in recycled aggregate concrete.

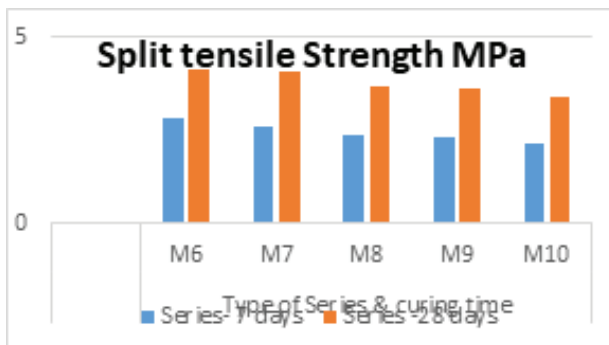


Fig. 5: Split tensile strength of M6-M10 specimen groups for 7- and 28-days curing

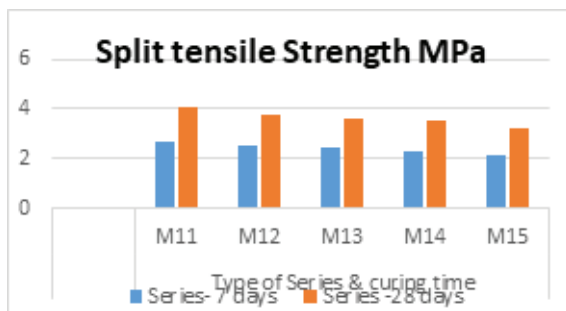


Fig 6: Split tensile strength of M11-M15 specimen groups for 7- and 28-days curing

Figure 6 presents the effect of incorporating GGBS into concrete mixes containing 0% RA and 45% RA on split “tensile strength. The mixes M-11, M-12, M-13, and M-14” achieve split tensile strengths higher than the target value, whereas the M-15 mix records a reduction of about 5% relative to the target strength. The existence of extra hydration products that build up within the cured concrete's pore structure is responsible for the strength increase, suggesting that application of GGBS improves mechanical behavior of recycled aggregate concrete. Based on these observations, replacing approximately 10% of the cement with GGBS appears to be the most efficient and cost-effective approach for improving both compressive strength and “split tensile strength in recycled aggregate” concrete.

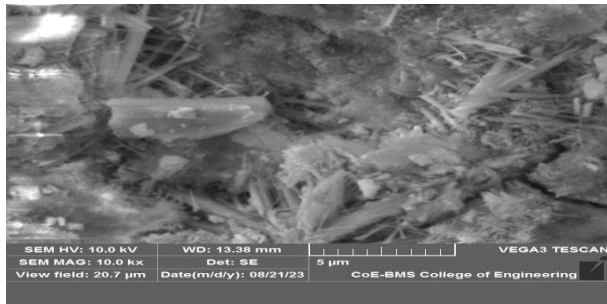
Microstructural analysis: Microstructural characteristics of concrete, which help explain variations in compressive strength at a microscopic scale, were examined using SEM analysis. Figure 5(c) and 5(d) present the SEM images for concrete containing 45 wt.% RA as a replacement for NA, while Figure 5(a) and 5(b) correspond to mixes with 20 wt.% fly ash and 45 wt.% RA. The SEM observations indicate that both RA- and NA-based concretes exhibit dense and continuous microstructures at later ages. These results further confirm that a 28-day curing period is essential for both natural and recycled aggregate concrete, as compressive as well as split tensile strengths were significantly higher at 28 days than at 7 days. As illustrated in Figure 6, insufficient curing (7 days) led to the development of porous and loosely packed structures, demonstrating inadequate hydration. In contrast, at 28 days, cementitious matrix and the RA/NA particles became increasingly compact and well bonded, and initial micro-cracks were restricted before widening into the matrix. For the mix containing 45 wt.% RA and 20% fly ash (Figure 5(c) and 5(d)), incorporation of fly ash reduced voids and enhanced formation of additional hydration products. This microstructural refinement aligns with the observed improvement in both compressive and split tensile strengths.

CONCLUSIONS

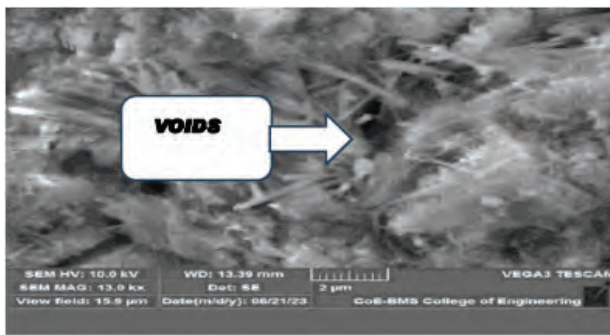
1. As proportion of RCA in concrete mix elevates, correspondingly concrete's compressive strength will gradually decline.
2. The 15% and 30% addition of RCA to concrete aggregate M25 concrete's “compressive as well as split tensile strengths are both more” than the desired mean strength.
3. Compared to the planned mean target strength of M25 concrete, the resulting concrete's “compressive strength as well as split tensile strength” are somewhat lower, ranging from 2% to 5%, when 45% of NCA is substituted with RCA.
4. When 60% of NCA is replaced by RCA, the resulting concrete shows significant drop in both compressive “strength and split tensile strength.
5. Replacement of natural aggregate with 45% RCA and incorporating ACM as Flyash & GGBS, both

split tensile strength and compressive strength are increased in” final concrete. These enhancements in strength properties exceed target strength of M25 concrete.

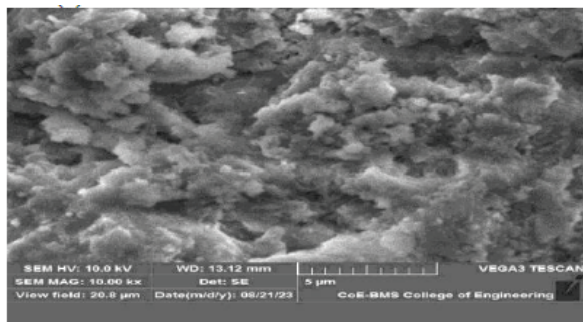
6. With 60% adding of RCA by replacing coarse NCA, Compressive strength & split tensile strength is lesser by 5% of than target strength of M25 concrete
7. So it may be concluded that, utilizing FA & GGBS as ACM's, 50% of recycled concrete aggregate can be used
8. FA or GGBS with 20 % replacement with cement gives higher strength than target mean strength



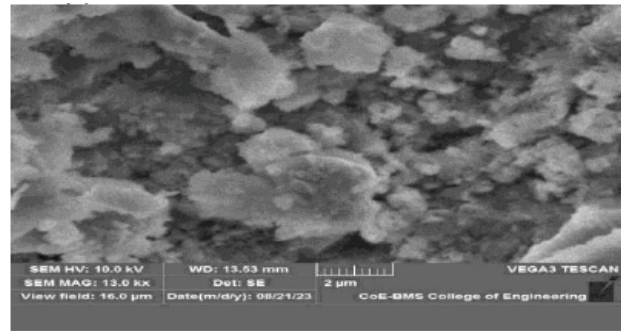
45 wt.% RA + 20% fly ash mix
45 wt.% RA + 20% FLYASH



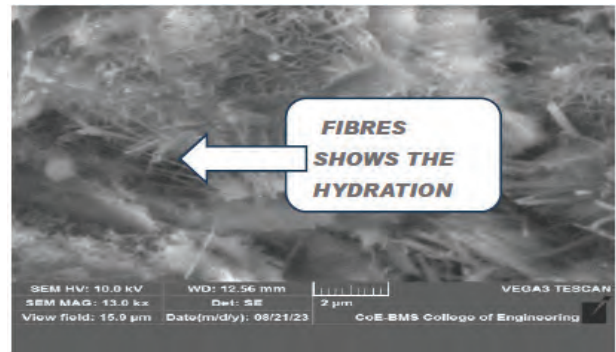
(a) 45 wt.% RA +20% FLYASH



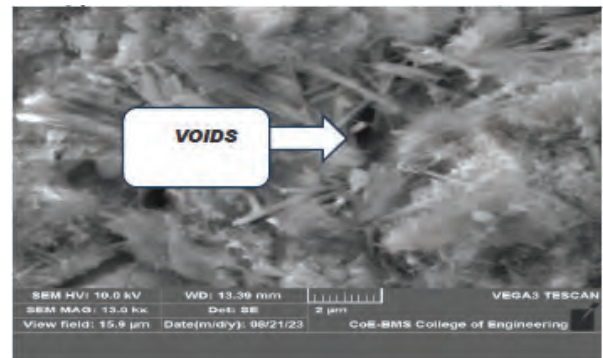
(b) 45 wt.% RA



(c) 45 wt.% RA



(d) 45 wt.% RA + 20% GGBS



(e) 45 wt.% RA + 20% GGBS

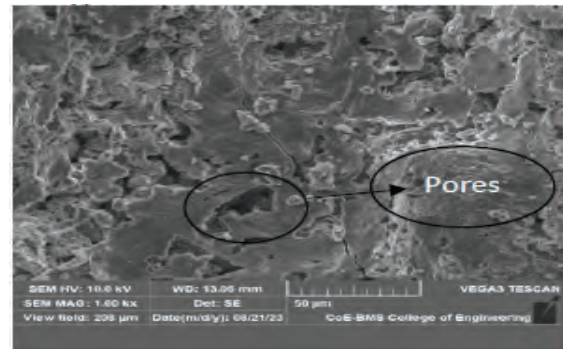


Fig. 6: SEM observations of concretes of 7 days curing age

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A Parametric Scheduling Framework for Building Elements using BIM

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ABSTRACT

Building Information Modeling (BIM) is an emerging and revolutionary tool that has been proven to improve the accuracy and efficiency of construction project planning. In this work, a parametric scheduling framework is proposed utilizing BIM's capabilities granted by Autodesk Revit, a modeling software. The framework works upon associating construction-related attributes with building elements allowing the scheduling of detailed schedules upon model properties. The scheduling framework permits automatic generation of tables or schedules element-wise, thus providing aid in planning, resource allocation, and project tracking. The study exemplifies that parametric properties like type, material, and phase information could also help during the designing process and be used to develop sophisticated and adaptable schedules. These surveys confirm that BIM-based scheduling will assist in discipline coordination and reduce manual errors and increase project efficiency.

KEYWORDS : *Building information modeling (BIM), Parametric modeling, Construction scheduling, Autodesk revit, Walls, Doors, Windows.*

INTRODUCTION

Most of the Construction companies are still stuck in legacy systems which has made knowledge sharing and improving processes regularly a difficult exercise. In the construction sector, work is typically sliced up and compartmentalized according to a rigid schedule that doesn't easily accommodate change or account for the entire project lifecycle. However, the use of modern tools such as Building Information Modelling (BIM) can support teams from different disciplines coming together in a more efficient way. BIM does work to change the way projects are planned and managed, including infrastructure projects, not just buildings.

The application of BIM in residential buildings has many advantages such as better visual, accurate

cost estimation, better coordination and lifecycle management. Beginning at the concept-stage, and continuing throughout the structure's life cycle, BIM facilitates a smooth workflow from design to facility management with less waste and fewer mistakes.

This study is approaching the development of 3D BIM model for residential building. Though BIM is already in limited use on infrastructure and elsewhere, there still does not exist a single plug-and-play method for applying it to all types of construction jobs. This research explores how BIM is currently used, and how it can be used to support design and planning in a new working method called drift design.

LITERATURE REVIEW

Utilizing BIM for Parametric Scheduling and project management is revolutionizing construction projects.

BIM enables in-depth digital models of buildings, and parametric scheduling shifts the project schedule as designs are modified among other things. This combination is what allows an up-to-date and accurate schedule. New research, for instance that of Zhao and Kim (2023), indicate how BIM - enabled scheduling updates itself as soon as a change occurs in the liquid world or resource, leading to preventing delays. Smith and Liu (2022) indicated that by using one BIM model by different teams, the planning of schedules are better aligned which result in less mistakes and misunderstandings. Some real -life examples, such as from Hassan and Elbeltagi (2023), demonstrate that this approach is efficient for complex residential buildings, thus resulting in more construction efficiency. In conclusion, integrating BIM and parametric scheduling enhances the precision of project schedules as well as facilitates more productive collaboration between teams.

METHODOLOGY

This approach starts from a comprehensive BIM model in which every door or window is characterized by its features (e.g., size, height, type and order of installation). These items are associated with respective activities in the work flow schedule as having durations and interdependencies. For instance, the fitting of doors and windows is expected to proceed after the structural work (framing & walls) is done. If the design changes (e.g. enlarging, re-ordering install or removing an installation part window), the schedule is dynamic and will change accordingly.

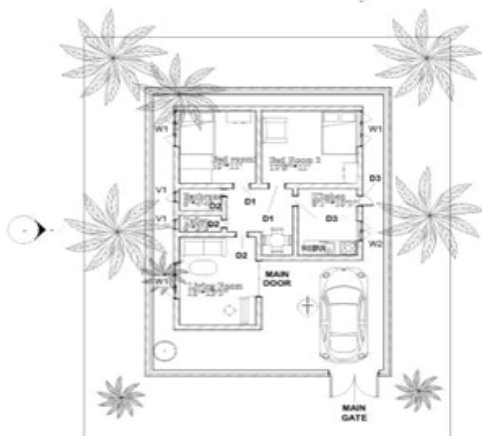


Fig. 1. Plan of residential building using Revit

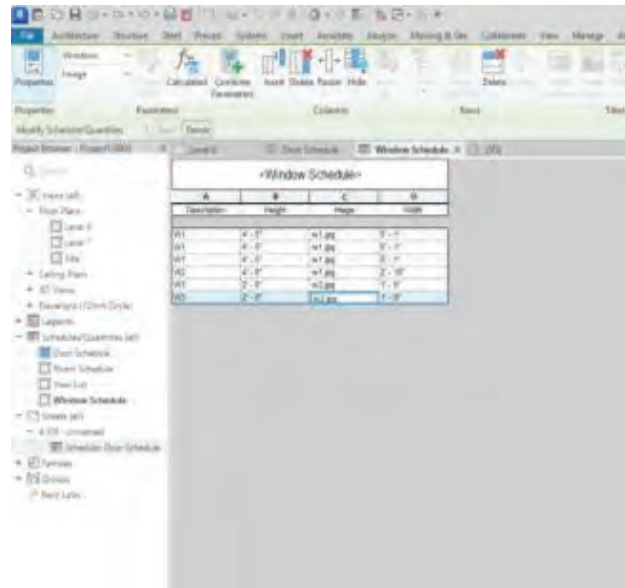


Fig. 2. Scheduling of Window using Revit

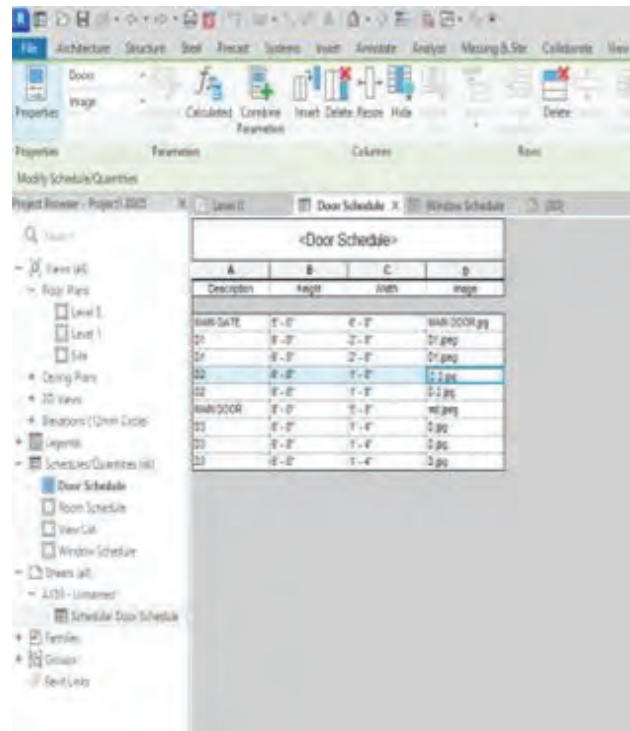


Fig. 3. Scheduling of Door using Revit

The implementation demonstrated the ability to generate schedules for door and window elements. Changes to design inputs such as selection, parameters were immediately reflected in the corresponding schedule outputs.



Fig. 4. Top view of building



Fig. 5. Front view of building

RESULT

To evaluate the effectiveness of the proposed parametric scheduling framework, a BIM -based model was developed using Autodesk Revit. Custom parametric families for doors and windows were created with key attributes such as height, size, description etc.



Fig. 6. Right side view of building

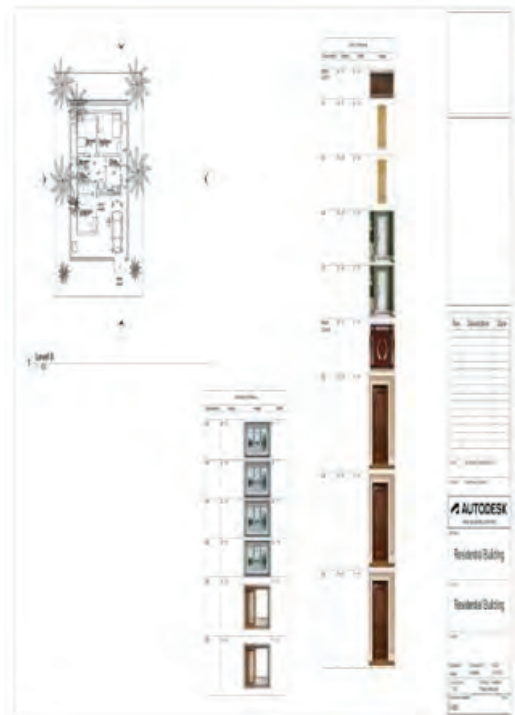


Fig. 7. Sheet of Residential Building Using Revit

The BIM- generated schedule sheet, developed using Autodesk Revit, contains detailed plan data for door and window elements. This schedule includes key parametric attributes such as type mark, dimensions, description.

CONCLUSION

The schedule automatically changed when window and door plans were updated, keeping things on track. The system spotted any issues early and fixed them right away. Scheduling with BIM improved communication between teams, reducing mistakes during installation. The automatic adjustments helped avoid delays, making sure window and door work stayed on schedule.

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Characterization of Construction and Demolition Waste for Construction of Rigid Pavement

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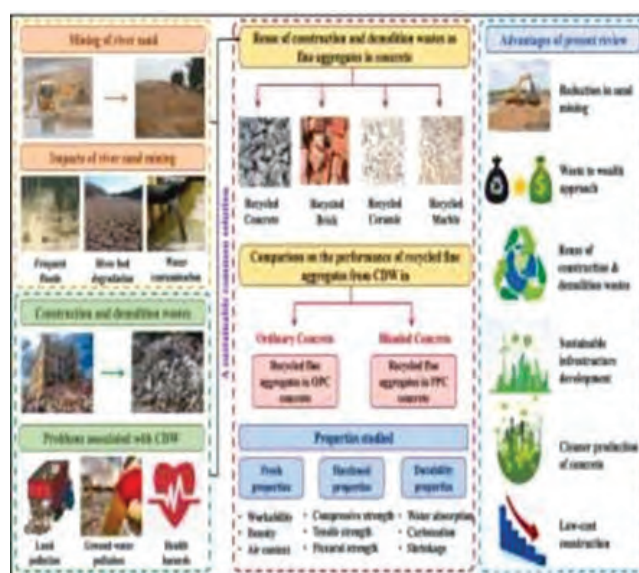
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ABSTRACT

Despite its negative impact on the environment, the building sector is vital to the growth of cities. Despite the fact that CD-W may be recycled and put to new use, their products nevertheless face difficulties in the market. Despite the largely favorable sentiment towards recycled items, several researches point the finger at the negative stigma around cycled goods. Recycling of C&D trash is increasingly prevalent in civil engineering construction projects. While some research has shown that C&D waste may be used as a sub-base or base material for road pavements, the fine-grained portion of this waste is no longer accepted as viable for use in pavement operations. An examination of the feasibility of using construction and demolition debris as fill for road embankments was examined in this study. The suitability of C&D waste aggregates for embankment fills may be ascertained by perusing the publicly available literature on their geotechnical and geo-environmental studies. Several publications also show that structural parts produced of recycled aggregate concrete may be viable, employing both small-scale components created in the lab and large-scale components made for real projects. Finally, this assessment has the potential to put customers' minds at ease and promote the increased use of recycled aggregate in civil engineering projects. The literature review, which drew from a broad database, gave special weight to articles published after 2020.

KEYWORDS : Construction and demolition (C&D) waste, Fine recycled concrete aggregate.

Graphical Abstract



INTRODUCTION

The urban population in India is expected to reach 50% of the total population by 2050, according to the country's fast urbanization trend [1]. The massive housing demands of India's rapidly growing urban population would need the construction of around 170 million dwellings by 2030 [2]. Therefore, it is expected that India would become a key participant in global construction sector by 2030, right up there with China & US [2]. However, there are two ways in which the expansion of the construction sector is bad for environment: first, it leads to an immediate demand for natural aggregates, and second, it necessitates the management of demolition debris from outdated structures. The construction industry's unregulated mining practices are largely to blame for loss of natural resources & resulting ecological imbalances. In a typical scenario, half of raw materials, 40% of energy, and 50% of waste are used in production of concrete.

When its service life is up (Chandru et al., 2023). Many scientific studies on CD-W recycling have started since the end of the second world war in affected nations like Germany, Japan, the UK, and the Soviet Union. This is done to make up for the discrepancy between resource demand and availability. As a result, a review of the literature regarding the scenario of CD-W generation and its application as fine recycled concrete aggregate (FRCA) in concrete and mortars with reference to their qualities is provided in this article.

MANAGEMENT POLICIES FOR CD-W GENERATION

The annual production of CD-W has risen to over 3 billion tones and is still rising. The management of CD-W through regulation and public awareness is a global concern that will protect the ecosystem [2]. As a result, the following information on global CD-W generation, existing laws, and policies for CD-W dumping and recycling is provided. The comprehensiveness of CD-W differs from country to country; hence the following study discusses a summary of data regarding significant nations:

India

India's GDP, which comprises 10% of the construction industry, is expanding at a rate of 10% annually

compared to the average global rate of 5.5%. India currently generates 530 million tons of CD-W, ranking second in the world. By 2030, it is anticipated that the built-up area will rise to 104 billion square feet (3. Ding et al., 2023).

An increase in construction activity will have a similar effect on CD-W generation. According to estimates, the amount of municipal solid garbage generated annually is increasing by 14.5 million tones, or 30%. The building industry generates 12 to 15 million tons of garbage annually, as per TIFAC. In addition to brick, masonry, soil, sand, gravel, metals, timber, bitumen, and other wastes received from CD-W, 23% of the total waste produced is made up of concrete. In Figure, you can see the CD-W's composition according to TIFAC.

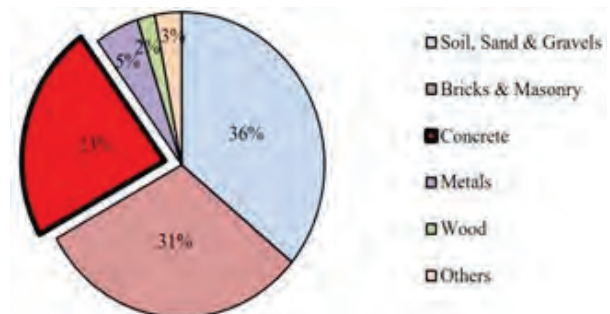


Fig. 1. A typical CD-W in India

When the Solid Waste Management Rule first came into effect, CD-W management was given equal treatment.

In order to control the handling and management of CD-W, the Ministry of Environment, Forests, and Climate Change (MoEFCC) has unveiled CDW Management Rules, 2016. The new regulation established an appropriate conduit for assigning responsibilities from the waste generator to the federal government. Given that local government is responsible for managing CD-Ws and that this management must be implemented within a certain period of time, a deadline has been established [3].

Various stakeholders were tasked with classifying waste at the collection and disposal point and making it accessible to the public (Zhikune et al. 2023). Waste management courses are encouraged to be taught in technical schools and universities by law. Additionally, it is suggested to academic institutions that, if necessary, they characterize their trash locally. As a result, the rule

intended to provide the majority of the nation with effective location-specific waste management solutions.

The capacity of the recycling facilities available in India is shown in Figure.2 along with the current state-by- state scenario for CD-W generation. The recycling potential in India has been hampered by lack of defined guidelines for using CD-W in new projects. By neglecting alternative resources, the standard code for aggregates (BIS 383-2016) promotes the usage of natural resources. However, BIS 456-2000 acknowledges using slag and broken over- burned bricks in plain concrete, but it makes no mention of using recycled concrete. In order to promote waste management and prevent the disposal of CD-W in landfills, India must take strong measures to define materials obtained from CD-W recycling.

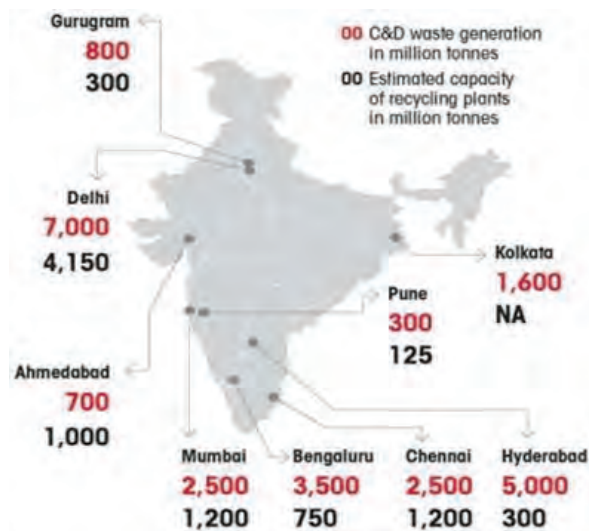


Fig. 2. Proposed recycling units and CD- W production in India

Australia

In the New South Wales region, Australia generates the most CD-W, followed by Victoria and Queensland. 55% of CD-W was recycled, according to a survey on waste generation and disposal (Ali et al., 2023). Instead of a centralized body, Australia's states and territory administer the garbage system. In Australia's capital cities, CD-W recycling rates are 81%, compared to 71% in South Australia.

Concrete, bricks, asphalt, and other construction and demolition waste make up 72.3% of CD-W,

of which 66% is trash. The "Towards Zero Waste Strategy" calls on Australian states to recycle 70% of their waste. Under Zero Waste SA, 2023, Victoria set a target of 80% material recovery from CD-W. By enacting a landfill charge on waste disposal, Australia followed New Zealand's lead and implemented waste reuse and recycling initiatives. Prior to the Australian Government's cost revision, a fee for disposing of waste ranged from \$42 to \$102, and it was continuously rising by \$10 annually up to 2016. The results of current initiatives, however, have yet to be seen, thus future development plans must be prepared accordingly.

United States

One of the main manufacturers of CD-W is the United States (US), which generates more than 500 million tons of the material annually. The United States Environmental Protection Agency (USEPA) deals with environmental and human health issues as well as how they intersect in the US. According to a thorough analysis on CD-W composition created by the USEPA, waste from Portland cement concrete and asphalt concrete accounted for 67% and 18% of the total in the years 2018–20, respectively. Around 85% of trash was reportedly recycled for aggregate extraction, according to Sharma et al. (2023). CD-W recycling in the US has a face value of 17 billion dollars, but the associated output is only about 7.4 billion. According to a Trivedi (2023) survey, just 23% of recycling facilities' utilization is restricted for the creation of fresh concrete, whereas 77% of recycling plants utilize recycled concrete for backfilling road bases.

Brazil

Brazilian producers of CD-W annually produce about 70 million tonnes. According to the amount of material, they separated CD-W into four groups called A, B, C, and D. The majority of waste falls into Class A (mortar, concrete, bricks, and soil excavation), Class B (other recyclable materials like plastic, rubber, metals, and wood), Class C (hazardous materials), and Class D (items that cannot be recycled or reused). Renovation and demolition activities generate 60% of garbage. The government has laws and regulations for recycling rubbish, but they are not enforced widely enough to have much of an impact [9].

Mexico

According to Andrade Salgado et al. (2022) Mexico produces 12 million tonnes of CD-W annually, or around 0.09 tonnes per person. Mexico has divided the CD-W into 4 Classes, similar to how Brazil has done. According to Estrada et al., 2023, at least 30% of Class A, which includes mortar and concrete, is intended to be recycled, and the waste is expected to increase by 15% annually to reach 100% [11].

Austria

In 2020, 35 million tonnes of CD-W were produced in Austria, and 87% of that amount was recycled (Liseane, 2022(a)). Austria has the greatest rate of recycling among European countries because it prioritises trash management. They try to properly enforce waste handling regulations in addition to recycling waste in an efficient manner. Waste management boosts the Austrian economy by 1235 million euros and creates 14779 new employments [12].

Denmark

Concrete trash dominates the CD-W in Denmark with more than 5 million tons, and the nation leads the world in garbage recycling. Road construction uses recycled CD-W in large quantities. According to the Danish Environmental Protection Agency (1999), Denmark generated twice as much CD-W in 2023.

France

The largest producer of CD-W in the entire European Union, France produced almost 246 million tones till 2023. France produces the most CD-Ws, yet it doesn't care to recycle the garbage. The garbage recycling rate was 45% up until 2023, which is significantly lower than the 45% European average (Ismail et al., 2023).

Germany

Over 80% of the 200 million tons of CD-W that Germany generates are recycled (Qiao et al., 2022; Zhang et al., 2023). Despite creating almost, the same amount of waste as France, Germany has maintained a far greater rate of recovery than France. The waste management business in Germany employs more than 2 lakh people and generates over 40 billion euros annually (Moschen-Schimek et al., 2023).

Italy

Around 40 million tons of CD-W are produced in Italy, where the recycling rate is about 75%. Twelve million tons of soil waste in total CD-W are not included in the recycling rate. More than 130 million tons of hazardous waste are generated in the nation each year through industries using a variety of treatment methods and CD-W (17. Hoang, 2021).

CHARACTERISTICS OF RECYCLED FINE

Liu (Liu, 2021), Karina (Karinaet al. 2023) and Silva Souza (Silva Souza, 2022) revealed that the physical characteristics of FRCA are mostly influenced by its texture and shape. According to the results of numerous researches, the vertical shaft impact (VSI) crusher's rotating speed has no effect on either the PSD of FRCA or the particle size. FRCA typically has an uneven shape and a porous texture because the attached mortar content greatly influences how it behaves (Jieet al., 2021).

According to Padmini (Jianget al., 2023), water absorption in FRCA rises as parent concrete's strength rises and falls as parent concrete's maximum aggregate size rises. Alan Verghese studied the water absorption of FRCA in 2023 and concluded that the more the mortar content, the bigger the specific surface area, and the greater the water absorption will be the result of smaller particle size.

However, Ramoset al., 2023 found that the micro-packing effect considerably reduced water absorption in pre-treated FRCA. According to Li et al., 2021, centrifuging FRCA at 2000 rpm for 10 minutes lowers its water absorption by 5- 7%.

According to Kou and Poon (2021), Martinez et al. (2023), Lee 2021, Stefanidou et al. (2023), and other sources, FRCA typically has a lower specific gravity than NFA, which leads to the creation of lower-density concrete. Researchers determined that the specific gravity of FRCA varied from 2.29 to 2.51. Another effect of the presence of adhering moist cement is this reduced specific gravity (Boudali et al., 2022).

Table 1 summarizes the findings of studies on the specific gravity, water absorption rates, fineness modulus, and bulk density of FRCA.

Resea- rchers	Specific Gravity	Water Absorp- tion (%)	Fineness modulus	Bulk Density (kg/m ³)
Qidan et al., 2021	2.49	14.5	4	1.04
Hong- pinget al., 2023	2.3	10.5	3.5	-
Li et al., 2020	2.2	13.5	3	1.32
Rostam et al., 2022	2.3	11.0	3.1	1.31
Su et al., 2020	2.1	5.0	3.0	1.26
Cha et al., 2020	2.4	9.8	1.14	1.36

CHARACTERISTICS OF CONCRETE WITH FRCA

The following is a discussion of the qualities of fresh and cured concrete that had varying amounts of FRCA:

Fresh-State Properties

Compared to laboratory-made broken FRCA, commercially manufactured FRCA contains substantially smoother particles, which offers satisfactory workability [24]. Due to mortar that has been attached, FRCA grains are harsher and have a more granular texture, which not only makes them more water-demanding but also necessitates more compaction energy due to greater particle friction.

Micro-Structural Properties

The form of FRCA particles was first discovered by Sharma in 2023 and then confirmed by Trivedi et al. in 2023. In order to determine the sphericity of FR particles, Sharma also used the photogrammetric technique. In front of a camera with a halogen light, the particles were discharged from a small vibrating conveyor. Using computer software, the continuously passing images of particles were analyzed for the length and width ratio and, as a result, the sphericity, which is the ratio between the circle with the particle's diameter

and the circle with an equivalent area of that particle. It was discovered that while the sphericity varied significantly between 1.04 and 1.21, the length by width ratio of NFA and FR particles was similar, falling between 1.27 and 1.39. This observation demonstrated that the angularity of FRCA particles was higher than that of NFA particles. Later, it was determined that the FRCA's increased angularity was to blame for the workability loss at the same water-to- cement ratio.

Hardened Properties

Testing concrete's compressive and split tensile strengths is the most crucial aspect to examine. Although splitting tensile strength is crucial for determining how a structure responds to service limit states, it is not as significant as compressive strength.

Table: 2 FRCA concrete's durability

Author	Wat er- cem ent rati o	Replac- em ent percent age	Compre- ssive strength (MPa)	Splitting Tensi- le Stren- gth (MPa)	Flexu- ral Stren- gth (MPa)
Shooshtar ia net.al., 2022	0.61	0	30	-	3
		25	29.3		2.5
		50	27.1		2
		75	26.8		2.4
		100	23.7		2.1
Hanan et.al., 2023	0.49	0	57		
		25	55		
		50	43.5		
Estrada et.al., 2023	0.52	75	50		
		100	41.5		
		0	43.7	4.3	
Ismail et.al.,2023	0.45	20	49.9	4.4	
		30	41.5	4.0	
		0	37.82		6.5
Ismail et.al.,2023	0.55	10	38		7.2
		30	37.99		6.9
		50	33		6.8
		100	36		6.6

PROBLEM IDENTIFICATION AND STUDY SCOPE

Following were identified research gaps after evaluating the works of many well-known researchers:

- It is crucial to follow the procedures of CD-W separation and characterization to ensure that Fine Recycled Concrete Aggregate (FRCA) behaves consistently and that the best possible use can be made of the waste.
- Although recycled CD-W is a well-known alternate supply of coarse aggregate, it could not produce results with increased strength when used 100% of the time. Therefore, it is anticipated that unused RCA can successfully replace sand.
- Therefore, after being properly processed in concrete and mortars, crushed coarse recycled aggregates may work effectively as RF due to their strength and consistently controlled grading.
- Due to attached mortar, the finer fraction of RF (size less than 0.15 mm) has hydrated cement that is still present. This material can be utilised in place of cement and fine aggregate in mortars and concrete.
- In addition to CD-W management, using RF as a simultaneous partial and full replacement of sand and cement in concrete and mortar has the potential to conserve a sizable quantity of natural resources.
- Lack of available natural sand and the perilous effects of indiscriminate river sand mining have compelled the search for adequate and sustainable alternatives.
- In landfill spaces, CD-W is left neglected due to a lack of understanding in the execution of CD-W management policies. In order to achieve sustainable development, it must be employed successfully in new construction.

CONCLUSION

An international case study of the building industry's use of waste management strategies for building and demolition debris is offered in this article. The scope was limited to just residential and high-rise buildings. Using

descriptive data, we outlined the potential for recycling and reusing. Over 70% of the debris from tall building construction came from concrete and aggregate. The debris generated during house construction, in contrast to that of high-rise structures, consisted of over 80% wood. The percentages of plastic, glass, ceramic, and packaging products were very low across all project categories, at 1%. Construction sites for high-rise buildings only sent 0.80% of their trash for recycling, in contrast to housing sites that sent 20%.

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Harvesting Harmony: Strategic Sustainability through Community -Centered Eco-Village Management in Gokul Dham

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ABSTRACT

In an era marked by ecological crisis and unsustainable urban expansion, the eco-villages emerge as vital prototype for regenerative living. This study presents an indepth case analysis of Gokul Dham Eco-Village, situated in Belagavi, North Karnataka, India, highlighting its innovative approaches to sustainable development through the integration of traditional and modern environmental practices. Gokul Dham demonstrates a self-sufficient model grounded in Vedic ecological principles, prioritizing zero-energy consumption, renewable resource use, and community-centric governance. Employing a mixed-methods research design such as incorporating surveys, interviews, document analysis, and field observation. This study investigates the eco-village's capacity to mitigate climate change impacts, reduce carbon footprint, and foster socioenvironmental harmony. It involves core practices such as organic farming, vermiculture, chemical-free construction and onsite wastewater treatment. The efficient water and soil management are evaluated for their replicability and scalability in broader sustainability frameworks. The Gokul Dham emphasizes in nurturing a resilient ecosystem and strong community ethos, offering a replicable model for decentralized and eco-friendly living. This case study subsidizes to the growing discourse on eco-villages as transformative spaces for environmental stewardship, rural innovation, and socio-cultural revitalization.

KEYWORDS : *Eco-village, Assist sustainability, Practices and challenges, Ecological practices, Zero-energy, Renewable energy, Solar energy, Green heaven, Water conservation, Organic farming.*

INTRODUCTION

When developing a community, a variety of natural resources and energy have been used. Many inhabitants rely on a broad variety of natural materials and energy, for their development and growth. As they diversify, their demand for resources increases, that majorly leads to greater environmental degradation and a growing disserver from nature. It acts as an example of a way of life that raises living standards while lowering environmental degradation and harm caused by human activity. It is claimed to be a deliberate strategy to restore the natural resources. A center for learning that encourages peaceful co-existence, the progression in agricultural practices, consumption of energy use

and the creation of only organic foods. According to Mithridate (2013), "the majority of energy consumption and pollution originate in the lifestyles of the citizens of developed countries." This has led some architects to reconsider design ideas, leading to new sustainable solutions. The current situation of a sustainable ecological environment must be taken into consideration given the fast growing demands of industry, agriculture, and urbanization. In emerging nations like India, environmental degradation is driven by factors such as mass extinction, pollution, deforestation, soaring carbon footprints, and agronomic land degradation. The overuse of nourishments, pesticides, sewage, and other pollutants contribute to 70 percent of the "dead zones" affecting global ecosystems.

With an annual production of 20 to 50 million metric tons, India is the fifth-largest producer of electronic waste. Ten states account for 70% of the nation's total production, and a United Nations report predicted that by 2020, e-waste in India would have increased by 500%. In emerging nations like India, environmental degradation is driven by factors such as mass extinction, pollution, deforestation, soaring carbon footprints, and agricultural land degradation.

The overuse of fertilizers, pesticides, sewage, and additional pollutants contribute to 70 percent of the "dead zones" affecting global ecosystems. The major environmental issues such as acid rain, global warming, desertification and the greenhouse effect contribute to ecological imbalance and pollution. Therefore, Rapid industrialization has a significant threat to the environment, and leads to depleting the natural properties and degrading ecosystems.

LITERATURE REVIEW

1. Rohan S. Gurav et al. (2024), they were studied on Gokul Dham Eco- Village and concluded saying there is significantly reduces carbon emissions through renewable energy and sustainable practices. The village fosters strong social cohesion and participatory community development. It demonstrates economic viability with sustainable agriculture and local initiatives. The model shows high potential for replication in rural development and sustainable living.
2. Mariyam Israr Ahmed Khatib et al. (2023) were studied on Sustainable Gokul Dham Ecovillage Case Study :A Model of community development with environmental management Ecological, economic, and social issues must all be balanced for sustainability (Agyeman et al., 1998). Environmental deterioration has resulted from rapid industrial growth and urbanization, particularly in nations like India.. The Key issues include pollution, deforestation, and rising electronic waste, which pose serious ecological and health risks. Recent studies stress the need for proper waste management, sustainable practices, and tools like ArcGIS to assess environmental impacts.
3. Hördur Haraldsson et al. (2012) conducted a study comparing ecological and conventional living in two Swedish villages, Toarp (ecological) and Oxie (conventional). Using dynamic simulation over a 50year period, they analyzed various scenarios to understand environmental impacts based on lifestyle differences. The study found that building ecofriendly homes only slightly reduced environmental effects. The most effective way to lower ecological footprint was by reducing food consumption and space heating, which together made up around 70% of the total impact.

PROBLEM DEFINITION AND OBJECTIVES

Problem Statement

- Source Sustainability Evaluation
- The transition to sustainable living is increasingly challenged by issues such as inefficient resource management, limited community engagement, loss of biodiversity insufficient education on environmental resilience.
- Despite advancements, challenges like global warming, continued dependence on non-renewable energy, and biodiversity loss continue to threaten the environment. This research seeks to understand how the village's simple, mindful, conversant living can serve as a guide towards achieving sustainability.

Research Purpose & Scope of Study

- The purpose of this research is to explore Gokul Dham Eco Village as a model of sustainable environmental living.
- The research focuses on establishing ways for various sustainable agricultural practices, harvesting methods and usage of energy and water.
- The study focuses on Gokul Dham Eco Village, which promotes sustainability and self-reliance by adhering to the concept of "Simple living and high thinking."
- The study explores the effectiveness sustainable practices, including practices like organic farming, water conservation, and alternative energy use.

- This study focuses on understanding the sustainable practices adopted by the residents of Gokul DhamEco-Village to establish conservation of water, energy, and developing various agro-methods

Objectives of the study

1. Examine the agricultural practices at Gokul Dham Eco Village
2. To facilitate strategic resource planning and optimization.
3. To understand the sources of energy consumption in Gokul Dham eco village.
4. To study the environmental impact of Eco village.
5. To promote the zero-energy consumption and sustainable living.
6. To understanding the various renewable energy sources adopted by Gokul Dham eco village
7. To study the sustainable water conservation and waste water management system.
8. To study building design to reduce the energy consumption.

STUDY AREA

The Gokul Dham Eco Village is situated in North Karnataka's Belagavi. It was established in 2003 and has a relatively small population. It is situated 40 kilometers from the Karnataka province's Belgaum metropolis, spanning 14 acres of verdant woodland and ten small nearby villages. There are 415 acres in total, of which 956.90 are built up. It is located in the Mahadayi watershed at 15° 40' 36" 6528N and 74° 16' 39.4644" E.

METHODOLOGY

The below Fig 1 both qualitative and quantitative analysis are described

The Gokul Dham EcoVillage has put into sustainable agro harvesting methods that poses organic farming, agroforestry, cover cropping, till farming, aquaponics, and rain water harvesting. These sustainable methods facilitate in maximizing proper resource utilization, enhances biodiversity and resilience and minimizes soil

disruption. Therefore, these sustainable practices have been done with zero consumption of energy and power. The water conservation and water distribution are also done in various eco-friendly practices that includes rain water harvesting, rooftop systems, mulching, recycled water use and drip irrigation that sustains in the practice of water conservation. As fire being a pivotal moment in human history for providing both illumination and warmth The Gokul Dham EcoVillage habitants primarily use fire, candles, oil lamps as their source of light and energy. They created Lamps by filling some natural objects like shells, hollow rocks etc.The Bio energy is also used in various practices as a source of energy that poses bio mass, bio gas and waste to energy.

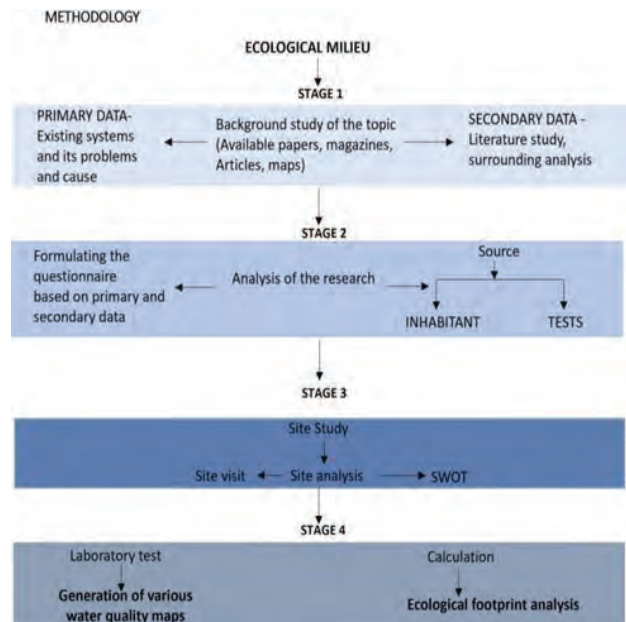


Fig. 1. Methodology Flowchart

RESULTS

Table 1 Results and Outcomes of Sustainable Practices

Source	Sustainable Practices	Outcomes/ results
1. Water	Rainwater harvesting Recycled greywater used for agriculture Sewage treatment Plant	Reduced freshwater usage by 70% Excellent water quality Self-sufficiency in irrigation

2. Energy	Use of solar panels for heating and cooking Energy efficient architecture	80% of energy needs met through renewables Lower greenhouse gas emission
3. Agriculture	Organic farming No chemical fertilizers or pesticides Crop rotation	Soil health maintained Increased crop yield Healthier food production
4. Waste management	Segregation of waste Composting and biogas generation from organic waste	Nearly zero landfill waste Biogas supports energy needs
5. Biodiversity	No deforestation Native species preservation Eco sensitive construction	High biodiversity levels maintained Balanced ecosystem m
6. Built environment	Passive design techniques Use of local and natural materials	Lower energy consumption for heating/cooling Reduced carbon footprint
7. Community practices	Participatory governance Sustainability education Skill training	Strong social cohesion Sustainable habits embedded in culture Resilient self-reliant mode

WATER QUALITY PARAMETERS

The below table shows several water quality metrics that were examined at three stations to assess the stream's quality.

Table 2 Water Quality Parameters

Parameters	Site 1	Site 2	Site3
pH	7.8	4.5	6.2
EC	100.35	312	122.02
TDS	67.25	475.8	266.68
TH	40.68	239.45	122.85
Calcium	55.62	45.08	28.17

Magnesium	6.49	16.8	21.85
Iron	0.06	0.39	0.12
Fluoride	0.03	0.08	0.6
Turbidity	1.5	2.39	4.16

WATER QUALITY INDEX VALUE

The Table 3 shows the water quality index value analysed at three different sites in the Gokul Dham Eco-village.

Table 3. Water Quality Index Value

Site	Water Quality Index Value
Site 1	15.25
Site 2	97.83
Site 3	42.34

The below Fig 2 shows a graphical representation of water quality index value by Sites Collected at three different location at Gokul – Dham Eco- Village

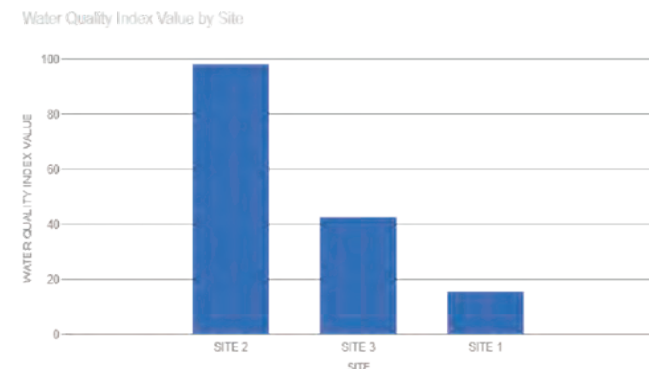


Fig. 2. Water Quality Index Value by Site

STANDARD WATER QUALITY INDEX VALUES

The following computation, table 4 below displays the three sites' different water quality index values, indicating that the water is of good quality (0-110).

Table 4 Standard Water Quality Index Values

Sl. No	Water Quality Index	Water Quality
1	0-110	Excellent
2	110-210	Good
3	210-310	Poor
4	310-410	Very Poor
5	>410	Unsuitable

DIMENSIONS

This comprises of the built-in area i.e. building and roads .The equivalence factor is taken as 2.63. The table below displays the Gokul Dham structure and covered roads.

Table. 5. Gokul Dham Ecovillage Building and Covered Roads

Buildings	Dimensions
Houses	233.9
Guest houses	380.91
Temple	45.15
Store rooms	92.98
Dairy farms	92.95
Buildings tools.	845.5
Roads	560.2

DISTRIBUTION OF LAND FOR RESIDENTIAL AND INFRASTRUCTURAL USE

The Fig. 3 illustrated below represents the distribution of consumed land for various infrastructural and residential purposes. It delivers a visual breakdown of how much land has been allocated among buildings such as houses, guest accommodations, temples etc.

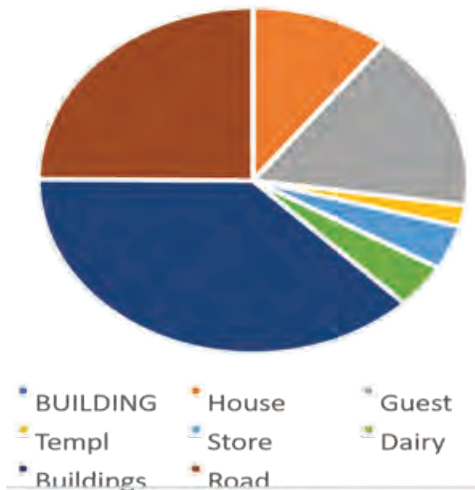


Fig. 3. Consumed Land

OBSERVATION AND DISCUSSION

The Ecological, social, and economic needs are balanced in the development of a sustainable ecological

ecosystem. This is demonstrated by Gokul Dham Eco Village's dedication to two fundamental ideals:

Conservation: The Habitants rely on renewable resources, safeguarding the bio- diversity and ecosystem.

Preservation: The focus is on managing and nourishing the environment in its naturalistic state, promoting a lifestyle that esteems ecological integrity and cohesion.

An Eco village is a traditional community that focuses to become socially , economically , culturally sustainable in all aspects. This case study highlights Gokul Dham Eco village as the model of sustainability, showcasing its self reliance and sovrnity with the practice of sustainable consumption . Key findings indicate that social dynamics and sustainable techniques play crucial roles in achieving eco friendly environment. The research implies that Eco villages retain valuable knowledge and cognition that could benefit the people in a broader aspect. It focus on prioritizing the sustainable practices like renewable energy, consumption of zero energy, water conservation, waste management and promoting a strong and holistic approach. Therefore The Gokul Dham Eco Village is served as a blueprint for adoption of broader sustainable practices in the minds of community

CONCLUSION

- 1 This research focuses on illuminating numerous instances when Eco-villages provide urban community beneficial sustainable principles. It highlights the environmental effects that have improved air quality, zero energy consumption and preservation of biodiversity.
- 2 The Ecological inhabitants focus to safeguard the biodiversity for future generations, emphasizing collaborative decision- making and create a strong bond among the community. This eco-village are self-sufficient, so there is a need to obtain and enhance innovative skills and techniques and add to your perspectives in areas.
- 3 The critical analysis's is to ascertain how much energy is effectively utilized to satisfy human demands. According to this study, the farming community's sustainable energy consumption methods are much more appropriate and sustainable.

4. Source of Water: Gokul Dham Eco village utilize recycled water and rainwater tanks to meet the wants of inhabitants and comply with local consumption targets. Another sources of water conservation or water collection is done through rain water harvesting. The water quality test is shown excellent, while treated sewage is repurposed for agriculture, as there are no harmful chemicals used in the eco village, assisted by a convenient and well-designed sewage treatment plant.
5. The generation and utilization of local energy have been systematically organized to foster a sustainable ecological environment. In the Gokul Dham Eco-Village, the integration of solar energy for water heating and cooking has significantly reduced greenhouse gas emissions. Notably, the presence and variety of energy-using appliances in households have had virtually no adverse effect on the residents' lifestyles. This achievement offers a valuable model for future urban planning initiatives. Such a master-planned approach has the potential to be scaled for cluster-level development throughout the region. Efficient water and energy management, along with the segregation of household waste, has already become an integral part of local practices and cultural values.

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Machine Learning-Enabled Groundwater Contamination Assessment and Forecasting of Quality Trends via PCA and Time-Series in Whitefield Region, Bengaluru

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ABSTRACT

Groundwater pollution poses a significant public health and environmental threat, particularly in urban industrial zones. This study evaluates the groundwater quality of the Whitefield Area, Bengaluru, India, using machine learning techniques implemented in Python. Thirty groundwater samples were collected across three consecutive years (2022–2024) during pre and post-monsoon seasons and analyzed as per APHA protocols. A three-phase approach was adopted: coarse-level temporal evaluation using Principal Component Analysis (PCA); fine grain assessment of critical contaminants; and time-series forecasting via the Prophet model. Results revealed that 76.67% of samples were non-potable, exceeding permissible levels of parameters including nitrates, hardness, total dissolved solids, calcium, magnesium, fluoride, chloride, iron, and chromium. Marginal but consistent upward trends were detected across key pollutants. The combination of traditional testing with predictive analytics proved effective in revealing dominant contamination drivers and aids in planning for future mitigation strategies.

KEYWORDS : *Groundwater contamination, Machine learning, Principal component analysis, Time-series forecasting, Python programming.*

INTRODUCTION

Groundwater Quality and Emerging Challenges
Groundwater represents one of the most vital resources on the planet, accounting for a substantial portion of the global freshwater supply for drinking and irrigation. With almost 50% of drinking water sourced from aquifers, increasing concern surrounds the degradation of groundwater quality due to anthropogenic activities and climatic variability (Gun, 2012). Recent studies emphasize that preventing pollution at the source is more sustainable than remediation, especially in developing urban centres (WWQA, 2021). Recent evidence stresses on more attention to reduce contamination adjacent to the well head (Lapworth et al., 2020; Ravenscroft et al., 2017). Factors contributing to aquifer pollution include industrial effluents, agricultural runoff, and improper

waste disposal. Systematic monitoring campaigns are therefore essential to trace and understand contaminant behavior, particularly near industrial clusters.

Application of Machine Learning in Groundwater Studies
Machine learning has emerged as a pivotal tool in environmental monitoring. In civil engineering, it supports the modeling of hydrological systems, structural integrity, and predictive analysis of water quality parameters (Deka, 2019). Data mining techniques like Support Vector Machine (SVM), Naïve Bayes (NB), K-Nearest Neighbour (KNN), and Classification Based on Association Rule (CBA) have been used to predict groundwater in Jordan (Aburub & Hadi, 2016). Techniques such as PCA, decision trees, SVM, and ANN are applied across domains, including river flow forecasting, contaminant detection, and aquifer mapping. PCA enables dimensionality

reduction and interprets interrelationships among variables influencing water quality. Previous studies have successfully employed PCA, KNN, ARIMA, and ANN to classify and forecast water pollution trends (Mahapatra et al., 2012; Hasan & Abdulazeez, 2021; Elhag et al., 2021). Factor analysis is also one of the multivariate statistical methods that is used to find the correlation between the parameters of data (Hulya & Hayal, 2017). In another study, a linear regression model is used to identify the important parameters to predict the overall water quality (Hamid et al., 2016). Water quality can also be monitored using wireless sensor networks, where sensors are used to measure the quality parameters (Kofi et al., 2017). The latest work includes the use of Artificial Neural Networks (ANN), a machine learning method, to monitor and predict the water quality parameters (Gasim et al., 2021). The present study builds upon these methodologies to understand long-term groundwater quality dynamics in a heavily industrialized belt.

MATERIALS AND METHODS

Study Area Description

The area chosen for study, Whitefield, is situated at about 22 km from Bangalore city in India, falling under the Topographic map 57 H/9. Whitefield has a huge conglomeration of industries, around 750 in number. The major threat in the study area is the dearth of water. The area faces a severe water crisis in summers, making the dependence on groundwater unavoidable. Bore wells run quite deep, and in most cases, 600 ft and above. The majority of these industries have to pay huge amounts of money to procure water from private tankers. With the massive increase in demand and alarming groundwater depletion in the area, the Bangalore Water Supply and Sanitary Board has started to supply water under the IV stage Cauvery Scheme, but only a few parts of the region are benefiting from this scheme (Shankar & Usha, 2023).

Sample Collection and Analysis

Groundwater samples (n=30) were gathered during pre-monsoon (May) and post-monsoon (October) seasons over three years (2022–2024). Samples were preserved per APHA (2002) guidelines. Each sampling station’s coordinates were logged using GPS.

Analysis encompassed physicochemical profiling per Indian Standard Drinking Water Specification (BIS 10500:2012), and involved spectrophotometry, titrimetric methods, flame photometry, and AAS. Figure 1 depicts the GIS study area map with groundwater sampling locations. The analysis techniques used for the determination of water quality parameters have been presented in Table 1.

Table 1. Analysis methods employed for parametric evaluation

Water Quality Parameter	Analysis methods
Chloride	Argentometric titration method
Sulphate	Spectrophotometry
Electrical Conductance	Conductivity meter
Total hardness	EDTA titrimetric analysis
Calcium	EDTA titrimetric analysis
Magnesium	Calculation though EDTA titrimetric analysis
Total alkalinity	Titration method (Neutralisation with acid)
Fluoride	UV-Visible Spectrophotometry
Nitrate	UV-Visible Spectrophotometry
Trace metals (Fe, Pb, Cu, Cr)	Atomic absorption Spectrophotometry
Sodium and potassium	Flame photometer
pH	Systronics Digital pH meter
Turbidity	Nephelo turbid meter
Acidity	Titration method (Neutralisation with base)

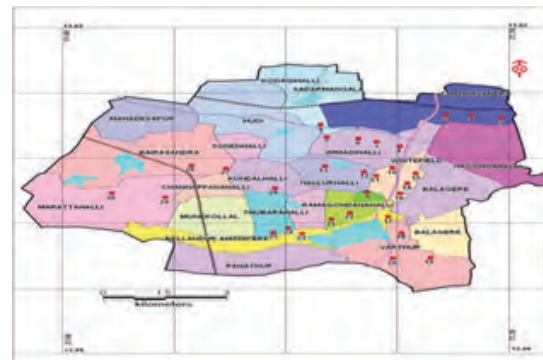


Fig. 1. Location map of sampling stations in Whitefield study area

Machine Learning and Statistical Techniques

Phase I: Principal Component Analysis (PCA) Python's sklearn library facilitated PCA for unsupervised feature extraction. Standard Scaler normalized the dataset, while Scree plots helped determine optimal principal components for each year. PCA revealed major contributing pollutants and clustered sampling stations by contamination levels. It calculates an uncorrelated set of variables (Hamed & Reda, 2019). These components are weighted average of the original variables given by the equation (1).

$$PC_i = w_1x_1 + w_2x_2 + \dots + w_nx_n \tag{1}$$

where w_i and x_i are the weights and the original variable, respectively. The method implemented in the present work was carried out using the Python programming language. The sklearn library provides plenty of methods for performing machine learning tasks. The data is imported into the data frame and standardized using the Standard Scaler method of the sklearn library. The attributes of the PCA module, such as explained variance_ and components, are used to get the amount of variance contributed by each principal component and loadings (correlation coefficients) respectively (Buitinck et al., 2013).

Phase II: Fine-Grain Analysis of Critical Contaminants. Focus was placed on parameters exhibiting significant variance and health risks: TH, Ca, Mg, Fe, Cl, NO₃, TDS, F, Cr, and pH. Descriptive statistics and temporal variation were assessed across years.

Phase III: Forecasting via Time-Series Modeling Using the Prophet module from Facebook's Kats library, trends of key pollutants were forecast over a five-year horizon. The quality of a river water was forecast using the ARIMA, Auto Regressive, Integrated, Moving Average model (Tizro et al., 2014). In another study, water quality parameters were estimated using remote sensing data. Prediction of water quality was done using ARIMA (Elhag et al., 2021). This step aids strategic planning by predicting future risks and identifying intervention priorities.

RESULTS AND DISCUSSION

Physico-Chemical Characterization

Post-monsoon data from 2022 revealed that 76.67%

of samples surpassed safe limits for one or more contaminants. Nitrate levels (>45 mg/L) and total hardness (>600 mg/L) were notably excessive, indicating health risks such as methemoglobinemia, congenital abnormalities, and kidney disorders (Mohammadpour et al., 2022; Giao et al., 2022; Shankar et al., 2008). Chromium, linked to electroplating and leather industries, was detected above toxic thresholds (>0.05 mg/L) in several samples. Cr concentrations greater than 0.05 mg/l can be extremely toxic and cause serious health effects (Christina et al., 2022).

Table 2. Physico-chemical analysis results for 2022 (post-monsoon)

Sl. No.	TH	Ca	Mg	Fe	Cl	NO ₃	TDS	F	Cr	pH
1	1094	212	124	85	1.5	124	502	0	242	20
2	653	124	65	54	2.5	115	208	0	258	77
3	458	91	46	92	1.4	0.00	275	0	222	55
4	325	52	22	64	0.5	0.00	70	0	60	17
5	715	144	70	112	2.5	0.25	342	4	280	84
6	655	111	114	100	4	0.22	404	2	300	100
7	1260	295	155	130	2.6	0.20	532	15	700	221
8	758	122	101	55	3	0.20	268	0	300	101
9	555	116	59	70	1.4	0.00	198	0	422	56
10	476	112	42	88	3.1	0.00	193	1	264	59
11	307	81	22	50	3	0.00	163	0	154	10
12	3002	512	402	100	1.4	0.00	244	0	2100	157
13	2110	392	368	78	4.1	0.10	370	3	1024	120
14	557	66	34	104	3	0.00	100	0	456	32
15	1248	224	115	175	4	0.10	330	16	610	32

18	1073	118	118	143	0.3	0.40	204	0	400	18	122	2.0	1830	2040	139	0	0	0	122	0.7
17	440	118	20	80	2	0.10	275	0	260	22	112	1.1	770	1220	122	0	0	0	784	0.0
16	287	72	25	88	3	0.14	204	0	110	34	80	2.0	310	840	024	0	0	0	723	1.0
15	400	128	15	45	4	0.48	30	0	86	31	324	1.5	610	1000	138	0	0	0	77	2.0
14	450	86	24	70	4	0.05	335	0	180	25	154	2.0	780	1100	038	0	0	0	750	0.0
13	513	104	26	88	3.4	0.11	203	4	374	15	104	1.0	850	1380	14	0	0	0	022	1.4
12	440	140	80	30	1	0.00	350	4	330	19	39	0.1	880	1350	18	0	0	0	8	1.0
11	287	72	25	117	4	0.43	204	0	264	84	33	0.2	750	1120	076	0.2	0	0	438	1.0
10	1540	244	140	180	5	0.22	345	0	380	21	100	1.6	2170	3480	044	0	0	0	712	10.0
9	1407	212	163	202	6	0.24	314	0	374	24	84	0.1	2880	4200	1	0	0	0	727	0.0
8	421	104	33	107	1	0.00	384	0	180	72	84	0.1	780	1220	13	0	0	0	024	1.0
7	112	21	13	31	0.3	0.30	100	2	80	12	24	0.4	200	480	138	0	0	0	700	0.0
6	310	122	44	80	0.3	0.14	310	3	172	21	10	0.0	600	980	144	0	0	0	630	2.4
5	300	80	16	38	1.3	0.00	384	0	244	20	30	0.2	780	1220	142	0	0	0	69	0.6
4	128	25	0	82	0.8	0.00	321	0	70	12	22	1.0	280	440	13	0	0	0	71	0.0

the moderate amount, and latter components show very little variability of the overall variance. The scree plot criterion looks for the “elbow” in the curve and selects all components just before the line flattens out.

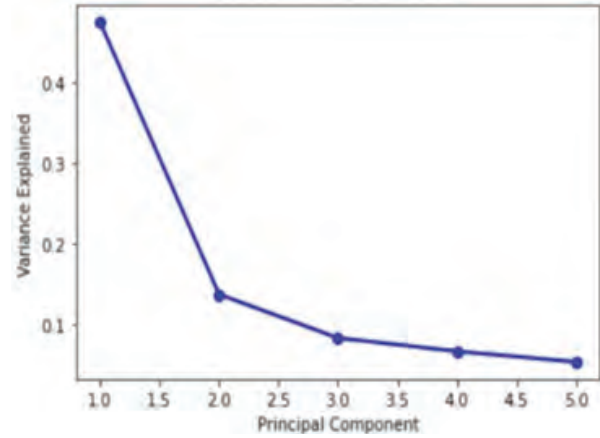


Fig. 2. Scree plot for 2022 data

The selection of the number of components is based on the scree plots. Sample scree plot of year 2022 shown in figure 2, which depicts the variability of the components. The first component explains maximum variability compared to the next few components, which explain the moderate amount, and latter components show very little variability of the overall variance. The scree plot criterion looks for the “elbow” in the curve and selects all components just before the line flattens out.

pH: unitless, EC in $\mu\text{s/cm}$, Turbidity in NTU, all other parameters in mg/L

PCA analysis and results

The present work was aimed at studying the trend/change in the water quality components over three years and predict the future trend. The study uses PCA to reduce the dimensions of the data and analyse it. The first step was to find the number of principle components to be formed. This was determined by the amount of variance that the components explain. The numbers of components retained are 4, 3, and 3 for the years 2022, 2023 and 2024 respectively

The selection of the number of components is based on the scree plots. Sample scree plot of year 2022 shown in figure 2, which depicts the variability of the components. The first component explains maximum variability compared to the next few components, which explain

Tables 3 illustrate the sample calculated principal component loadings for year 2022

Table 3. PCA results for 2022 data

Variable	PC1	PC2	PC3	PC4
TH	0.327	0.013	-0.014	-0.051
Ca	0.319	-0.002	-0.062	-0.074
Mg	0.327	0.034	0.020	-0.027
Na	0.124	-0.470	0.124	0.076
K	0.034	-0.354	-0.421	0.252
Fe	-0.014	-0.132	-0.590	-0.153
HCO3	0.163	-0.279	0.369	-0.109
CO3	0.026	-0.307	0.140	0.063
Cl	0.318	0.096	0.050	0.077
NO3	0.168	-0.236	0.304	0.370
SO4	0.204	-0.207	-0.367	-0.301

PO4	0.285	0.045	-0.077	0.018
TDS	0.325	-0.077	-0.021	-0.025
EC	0.327	-0.089	-0.028	-0.030
F	0.224	0.311	0.017	-0.071
Cu	-0.039	-0.042	-0.214	0.728
pH	-0.000	-0.000	-0.000	0.000
Cr	0.225	0.314	0.001	0.162
pH	-0.042	-0.337	0.107	-0.272
Turbidity	0.265	0.167	-0.067	0.109

Water quality trend in 2022

The results show that the first component (PC1) is the indication of the measurement of salts in the water, contributing to the variance of 47% of the total 76% variance. TH (0.327), Ca (0.319), Mg (0.327), Cl (0.318), TDS (0.325), EC (0.328) are highly correlated components with loadings that are highlighted in bold in Table 2(a). The second component (PC2) accounts for 13% of variability in association with negative loading of sodium (-0.470). This component is the measure of the decrease in sodium. The third component (PC3) accounts for 8% variance with a strong negative loading of iron (-0.57). This component is the measure of the decrease in the iron content in water. The fourth component (PC4) shows 6% variance in association of copper with a strong positive loading of 0.728. Copper can get into the drinking water as it passes through the plumbing system. Plumbing systems with copper parts fewer than three years old usually do not have the time to build up this protective coating.

Water quality trend in 2023

The results show that the first component (PC1) is highly influenced by the electrical conductivity of water with a strong positive loading of 0.762 and moderately influenced by Total hardness (0.36). This component accounts for 47% of total variance of 73%. Compared to 2022 trends, there is a marginal reduction in salts like TH, Ca and Mg. The second component (PC2) which contributes to 15% of variance is influenced by the strong negative loading of sulphate (-0.625) and positive loading of Cl (0.564). This component is an indication of decrease in sulphate. The third component (PC3) contributes to 8% of variance, continuing the negative influence with component of sulphate (-0.512)

and also total hardness (-0.560). This component shows the measure of decrease in the total hardness of the water. The results also show major change in the pH value compared to 2022 results. There is negligible impact of pH on the components.

Water quality trend in 2024

The first component (PC1) accounts for 50% variance of the total variance of 73% and is associated with positive loading of salts like total hardness, calcium and magnesium, chloride), and electrical conductivity. It shows that the number of salts in 2022 has again recovered by 2024. The second component (PC2) accounts for 15% of the variance associated with positive loading of 0.46 on sodium and moderate on bicarbonates (0.33). Third component (PC3) accounts to 8% of variance and is associated with negative loading of Iron in the water. This component is the measurement of the decrease in iron in the water.

In the second phase of the analysis, important water quality parameters were considered for study, and also the first phase outcomes aided in the extraction of influential components. The variation of these components with respect to mean, standard deviation, minimum, and maximum is studied as shown in Table 4. This also helps in understanding the distribution of values across three years.

Table 4. Statistical Analysis of Critical Water Components

Variable	Mean			Standard Deviation			Minimum			Maximum		
	2022	2023	2024	2022	2023	2024	2022	2023	2024	2022	2023	2024
TH	757.9	751.2	781.8	691.0	681.4	700.7	88.0	92.0	98.0	3111	2982	3070
Ca	152.6	156.9	163.1	122.7	124.5	127.7	18.0	21.0	25.0	582.0	582	596
Mg	85.00	87.51	91.20	90.31	92.19	94.83	6.0	7.0	7.00	402.0	402.0	412
Fe	0.25	0.26	0.27	0.37	0.37	0.38	0.0	0.0	0.0	0.0	1.49	1.51
Cl	399.5	406.8	417.6	447.6	443.9	449.5	49.0	49	40.0	2142	2108	2120
NO ₃	52.41	53.93	57.35	60.23	60.67	61.78	8.00	8.0	10.0	332.0	332.0	344.0
TDS	1153.0	1192.6	1237.3	866.86	877.51	902.32	210.0	230.0	248.0	3940.0	3940.0	4010
F	1.44	1.45	1.47	1.37	1.38	1.38	0.2	0.2	0.14	6.09	6.09	6.12
Cr	0.09	0.10	0.10	0.51	0.50	0.51	0.0	0.0	0.0	3.00	2.84	2.86
pH	7.22	7.22	7.22	0.72	0.73	0.73	5.1	5.1	5.12	8.24	8.25	8.30

The third phase of the work deals with predicting the values of the critical components for the next few years based on the previous trend. Figure 3 show the future trend of the sample critical water components (Ca, NO₃).

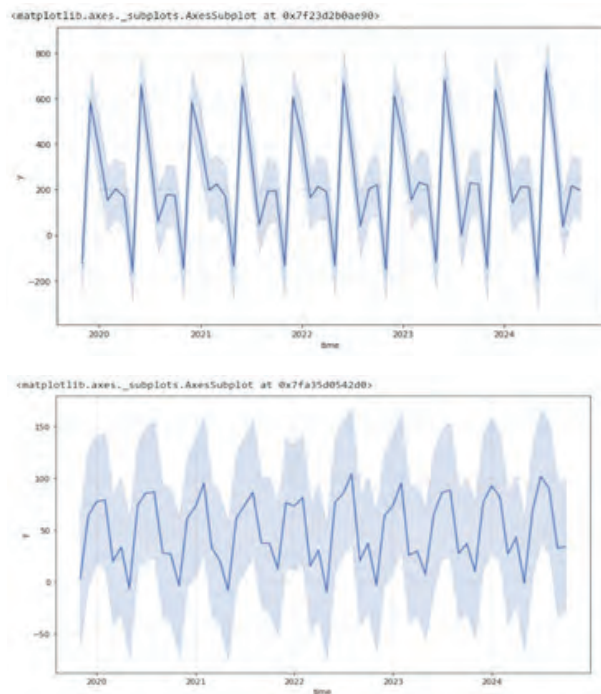


Fig. 3. Future trend of calcium and NO₃ through 2027-29

Summing up,

- 2022: PC1 indicated salt-related components (TH, Ca, Mg, Cl, TDS, EC), contributing 47% variance. PC2 highlighted sodium depletion; PC3 and PC4 reflected decreases in iron and increases in copper, respectively.
- 2023: EC dominated PC1 with 47% explained variance; PC2 indicated declining sulphate levels, while PC3 captured marginal reductions in TH.
- 2024: PC1 reaffirmed elevated salts, reversing 2023's moderation. PC2 tracked sodium and bicarbonate rise, and PC3 denoted continued suppression of iron content.

CONCLUSION

The study demonstrates a robust machine learning approach for groundwater quality analysis and projection. In the Whitefield Area, the combination of PCA and time-series models unveiled pollutant trajectories and their ecological implications. Since the study area is highly prone to industrial effluent discharges, the present work focused on the studying the changes in water quality parameters that happened over 3 years. The results revealed that there is an increasing tendency of the water quality parameter concentrations, though the variations are marginal. With 76.67% samples showing non-potability and multiple contaminants breaching safety thresholds, the findings underscore the urgency of targeted water governance. Forecasting provides actionable insights for municipal bodies and policymakers to implement remediation and regulatory strategies.

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Hampi-Sustainable Tourism Destination: Tourist's Sensitivity

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ABSTRACT

There is no denying the tourist industry's rising stature as a force for economic growth and its promise as a development instrument. The tourist industry not only drives economic expansion, but it also raises living standards by providing several types of jobs on a massive scale. Promoting environmental preservation, honoring cultural diversity, and enhancing global peace are all aspects of this that it underpins. Hampi, a UNESCO World Heritage site, is one of India's most popular tourist destinations. With its stunning surroundings and rich history, Hampi shows travelers the Vijayanagara Empire's majesty. The main goal of this study is to comprehend, assess, and evaluate tourist sensitivity (the perceived perception of visitors) across national and international demographics. The scope of the current research is limited to tourists that are visiting places in and around Hampi, measuring the differences of their perception across demographical backgrounds with regard to sustainable tourism adopted to promote Hampi to be prominent Cultural & Heritage site that promotes the sustainable tourism.

KEYWORDS : *Sustainable tourism, Culture and heritage, Tourist sensitivity.*

INTRODUCTION

As a development instrument, the tourist industry is unquestionably growing in importance and impact. It not only drives growth but also enhances people's lives by creating a wide range of job opportunities. In addition, it is essential in preserving the environment, honoring various cultural heritages, and fostering global peace. Because of its rapid expansion, the tourist industry is having a multiplicative influence on other connected fields by increasing regional development and job opportunities. In more developed countries, domestic tourism has emerged as a launching pad for broader tourism growth. It has tremendous potential to positively contribute to sustainable development objectives and can provide necessary resources for protecting our natural and cultural heritage.

Tourism will employ 12.57 percent of India's workforce in 2022–23, according to the Ministry of Tourism's 3rd Tourism Satellite Account (TSA) report. The industry is one of the biggest contributors to the economy, with 5% contribution to India's GDP. Foreign visitors

visiting India have increased from 1.28 million in 1981 to 1.68 million in 1991, 2.54 million in 2001, and 10.93 million in 2019. Unfortunately, the 2020 lockdown and COVID-19 epidemic plummeted their numbers. Tourism started slowly but picked significantly once the economy expanded. Over 87% of pre-pandemic levels, India's FTAs increased 47% from 2022 to 2023 to 9.52 million.

International visitors reached 18.89 million, up 5.47 percent from 17.91 million in 2019. Domestic tourism to all 50 states and territories will rise 9.3% from 2011–2023. Foreign tourist visits have increased throughout time, although in 2001, 2012, 2020, and 2021, they fell. The 2011–2023 CAGR of foreign tourist visits to all states and territories was 0.1%. The number of domestic tourists increased by 45.0% in 2023 compared to 2022, while the number of international tourists increased by 124.1%.

LITERATURE REVIEW

To preserve and promote cultural heritage, sustainable tourism is essential, since it mediates between the two

competing goals of economic development and the protection of cultural treasures. The tourism industry can promote awareness and offer much-needed finances to preserve cultural heritage, customs, and historical sites. (Jiawei, A.Z. et. al. 2024). Poor tourism management, however, has the potential to negatively affect the cultural resources in the form of degradation of the environment, commercialization, and overcrowding. Sustainable tourism helps preserve cultural assets by generating funds for conservation and restoration. Revenue from guided tours, entrance fees, and cultural performances can be used to support conservation efforts, thus helping to preserve the sites for future generations (Anh, et. al. 2024). When local people are involved in tourism, this translates to increased understanding and appreciation of their cultural heritage, thus bringing with it a sense of responsibility and pride in its protection. The creation of policies and procedures aimed at preserving cultural assets places a premium on sustainable tourism. Institutions and governments are more likely to enact measures that limit tourism's negative impacts, such as limiting entry to fragile regions, controlling the amount of tourists, and encouraging eco-friendly behaviors (Hosseini, K et. al. 2021). These approaches protect cultural treasures from overtourism. Cultural understanding is promoted by sustainable tourism. Engaging with local cultures helps travelers learn about their destinations' history and traditions. This enhances visitor culture and preserves language, music, dance, and crafts in our globalized world (Caciora, T et. al. 2021). Tourism has several consequences. It may improve the economy in several ways. Tourism is vital to many developing countries' economies and employment markets. Tourism may impact the ecology, socioeconomic inequity, and cultural identity if not handled effectively. Popular vacation destinations are experiencing overtourism. Sustainable tourism considers economic, environmental, and social concerns. Local economies may become more robust with sustainable practices, say supporters.

The research highlights that destinations embracing sustainable practices tend to enjoy longer-lasting appeal and attractiveness. Take Costa Rica, for instance; the rise of eco-tourism there has not only helped preserve its rich biodiversity but has also significantly boosted tourism revenues. When we talk about integrating

natural values, we're referring to the efforts made to recognize the importance of the natural environment in tourism development (Ferretti & Comino, 2015). This includes protecting ecosystems, managing natural resources sustainably, and minimizing negative environmental impacts (Mondal & Palit, 2022). In the realm of sustainable tourism development, focusing on integrating natural values is crucial to ensure that tourism can bring economic benefits while maintaining the delicate balance of the natural environment, which is itself a major draw for visitors (Streimikiene et al., 2021). Moreover, incorporating natural values into the lives of communities near cultural heritage sites is vital for fostering a sustainable and harmonious environment (S. Zhang et. al. 2023). Respecting and protecting the natural resources around these cultural monuments preserves their beauty and improves local communities' quality of life. (Jang & Mennis, 2021). Preserving the stunning landscapes around heritage sites can create recreational and educational spaces for the community, helping to deepen their connection with both cultural and natural heritage (Maxim & Chasovschi, 2021).

HAMPI AS A TOURISM DESTINATION

Located at the World Heritage site of Hampi, one of India's most intriguing tourism spots, is a treasure trove of scenic beauty and rich heritage. Hampi provides the tourist with a glimpse of the glory of the Vijayanagara Empire. This article discusses Hampi's cultural and historical value, tourism's good influence on the local economy, the need to preserve cultural heritage, and sustainable tourism's future. The Vijayanagara Empire called Hampi its capital from the fourteenth through the sixteenth century. The empire was marked by unparalleled wealth, religious tolerance, and remarkable architectural developments. The Hampi landscape is dominated by a series of ancient temples, palaces, and fortifications that exhibit the architectural preference of the period. The Virupaksha Temple, the Vittala Temple with its legendary stone chariot, and the royal enclosure with imposing structures such as the Zenana and the audience halls are some of the prominent attractions. This plethora of architecture is a fascinating mix of Dravidian flavor and intricate stonework. However, the tourist surge has raised worries about Hampi's cultural and historical legacy. Tourism degrades the environment

and commercializes local culture. The tourist arrival has strained the infrastructure and resources of the area. This has necessitated several stakeholders, including the Archaeological Survey of India, local government, and non-governmental organizations, to promote sustainable tourism activities that will balance the economic advantage with the preservation of heritage.

PURPOSE, SCOPE AND METHODOLOGY

The purpose of this research is to compare tourist sensitivity (the perception of visitors) among national and international tourists from different demographics. The scope of the current research is limited to tourists that are visiting places in and around Hampi, measuring the differences of their perception across demographical backgrounds with regard to sustainable tourism adopted to promote Hampi to be prominent Cultural & Heritage site that promotes the sustainable tourism.

METHODOLOGY

To attain the research objective, researcher has adopted Survey method where the primary data is (responses obtained) through a structure questionnaire which is tested scientifically. Questionnaire was administered as both Google forms and manually according to the ease of respondents (preference of respondents). Thus collected data is supported with secondary by extensive literature survey. Thus collected is analyzed by adopting appropriate statistical tools; ANOVA through SPSS software to draw statistical inferences. Suggestions and recommendations are presented based on the outcome of the analysis.

Sample design is an important aspect of research where researcher identifies the population of study from which sample frame is drawn and finally arrive at specific sample size. Sample design lay down the frame of identifying sample size and sample units scientifically by adopting systematic process which includes process, methods and formulae.

Sample Design and Sample Size

Population of the current study is identified separately for tourists. The population size of the tourists including both domestic and foreigner is indefinite. According to the reports, during season, the footfall of the tourists is 5000 per day and during off season the number falls to

2000 tourists per day. As the population size is enormous, researcher has chose 100 different tourists from national and international arena that are stratified based on their Age group (Stratified Sampling) where 20 tourists from the each Age group were chosen randomly (Simple Random Sampling). As the researcher received only 67 completely filled questionnaire, further inferences are drawn for the sample of 67 tourists.

Construct: A construct is an idea interpreted in a specific way which is used to account for a particular occurrence. Unlike in case of constructs, concepts may either be singular or multiple and blends of interrelated ideas that encompass the primary theme as well as provide clear operational definitions needed for the study at hand. As researcher intends to find the covariance among the preferences of Tourists- Hampi as a tourist destination, perceived perception of their experience visit, encountered during their stay gyrating around the Sustainable tourism Strategies.

Construct Measurement: Rensis Likert Scale

While a doctoral student at Columbia University, psychologist and educator Rensis Likert (pronounced LEE-kurt, not LIE-kurt) wanted a "scientific" way to measure subjective psychological views. His 1932 book *A Technique for the Measurement of Attitudes* demonstrated how to use Likert scales. This research employed a 5-point Likert Scale (strongly disagree to strongly agree).

Perception is a set of 17 statements that assess tourists' opinions about Hampi and their whole experience. The construct measurement adopted is Likert Scale of Five points rating ranging from strongly disagree to strongly agree.

The reliability test is carried out using Cronbach's Alpha for 17 attributes for the sample size of 67 Tourists. According to the case process summary, none of the cases were excluded. The reliability statistics :Cronbach's Alpha 0.906 and Alpha Based on Standardized Items is found to be 0.907 for the current study. Item statistics of the construct "Perception" is summarized in the Tabke-3, the mean sores of the attributes 34.69, standard deviation 9.215 and total variance of 147.53 for the N=67. It is also observed, the Cronbach's Alpha for the attributes is found to >then

0.85 which falls under the category of very good and hence considered for the further analysis.

Factor-Analysis: Tourists Sensitivity (Perception)

Before doing factor analysis using the Extraction Method—Principal Component Analysis, varimax rotation with Kaiser—Meyer-Olkin, and Bartlett's Test, we ensure that our samples are sufficient. After 21 rounds of normalization and rotations, the KMO value for the 67-item sample was determined to be 0.800., $\chi^2=517.516$, df (degree of freedom) = 136 and is found to be significant at $p=0.000<0.05$ indicates the significance.

Table 1: KMO and Bartlett's Test for Perception

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.800
Bartlett's Test of Sphericity	Approx. Chi-Square	517.516
	df	136
	Sig.	.000

Communalities values of all the attributes under construct Perception. The factor loadings that are

>0.5 are considered for the further analysis excluding attributes having factor loadings <0.5 . Hence, 15 attributes under construct “Perception” are considered.

Ascertaining Tourist’s Sensitivity

Tourists sensitivity of tourism and promoting Hampi as Sustainable tourism destination is ascertained using ANOVA test across the variables; Gender and Age group to identify the covariance among and between the groups identified. The sensitivity (Perceived perception) is measured through 15 different attributes that are attributed to new factors (extracted 15 attributes & identified variables; Infrastructure, Culture & Heritage and Sustainability based on factor loadings, grouping of 5 attributes each) across gender and Age group of the tourists that visited Hampi during “Hampi Utsava”. The preposition to measure the covariance is framed based on the literature review of empirical studies.

Ho: No significant tourist’s sensitivity variances are identified across gender and age.

H1: Significant tourist’s sensitivity variances are identified across gender and age.

Table-2: ANOVA Results for Gender & Sensitivity of Tourism

Gender		Sum of Squares	df	Mean Square	F	Sig.
Infrastructure	Between Groups	47.283	4	11.821	36.322	.000
	Within Groups	325.772	65	.325		
	Total	373.056	67			
Culture & Heritage	Between Groups	50.908	4	12.727	28.683	.000
	Within Groups	444.157	1001	.444		
	Total	495.065	1005			
Sustainability	Between Groups	6.319	4	1.580	5.584	.000
	Within Groups	283.216	1001	.283		
	Total	289.535	1005			

Source: Pilot Survey Data

It is elucidated from Table-1, a significant differences are noticed between male and female for the variable Infrastructure at $F= 36.322$ at $p=0.000<0.05$. Similarly significant differences are noticed for Culture & heritage ($F= 28.683$, $p=0.000<0.05$) and Sustainability ($F=5.584$, $p=0.000<0.05$). Infrastructures vary most by gender, followed by culture & heritage and sustainability. Age and tourist sensitivity ANOVA findings are in Table-2.

The study's age categories include 1-20, 20-40, 40-60, and above 60. Most visitors are male and aged 20-40, followed by 40-60. With the purpose of identifying the existence of variances with regard to tourists sensitivity, has carried out ANOVA test and based on the results, TuKey LSD test (Mutliple comparison) is also carried out to locate the covariance between among groups.

Table-3 indicates, the significance of the differences for infrastructure (F=9.175, p=0.000), Culture & Heritage (F=8.404, p=0.000) and Sustainability (F= 4.868, p=0.001). But the major differences are observed for Infrastructure, followed by Culture and heritage.

Table 3: ANOVA Results for Age and Sensitivity of Tourism

Age		Sum of Squares	df	Mean Square	F	Sig.
Infrastructure	Between Groups	13.194	2	3.299	9.175	.000
	Within Groups	359.862	65	.360		
	Total	373.056	67			
Culture & Heritage	Between Groups	16.085	2	4.021	8.404	.000
	Within Groups	478.980	65	.479		
	Total	495.065	67			
Sustainability	Between Groups	5.525	2	1.381	4.868	.001
	Within Groups	284.010	65	.284		
	Total	289.535	67			

Source: Pilot Survey Data

Tukey LSD Test is carried out to know the differences among the age groups. With the exception of those aged 60 and higher, there is a discernible difference in infrastructure between the 1–20, 20–40, and 40–60 age groups. In comparison to other age groups, the 20–40 year olds stand out in the 1–20 age bracket. When 40-60 years group is compared with other groups, differences are significant for 60 and above years. When above 60

years group is compared with others, no significant differences are noticed for any group. Hence the differences exist between 1-20, 20-40 and 40-60 years of age group for infrastructure facilities. Similarly, for culture & heritage differences does not exists for 40-60 years of age group and for sustainability, differences does not exists for 1-20 and 20-40 years of age groups but are significant for above 60years of age group.

Table 4: Multiple Comparisons

Dependent Variable	(I) Age Group	(J) Age Group	Tukey HSD				
			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Infrastructure	1-20 Years	20-40 Years	-.19763*	.06564	.022	-.3770	-.0183
		40-60 Years	-.12401	.06284	.280	-.2957	.0477
		60 & Above	-.36015*	.06517	.000	-.5382	-.1820
	20-40 Years	1-20 Years	.19763*	.06564	.022	.0183	.3770
		40-60Years	.07362	.05939	.728	-.0887	.2359
		60 & Above	-.16252	.06185	.066	-.3315	.0065
	40-60Years	1-20 Years	.12401	.06284	.280	-.0477	.2957
		20-40 Years	-.07362	.05939	.728	-.2359	.0887
		60 & Above	-.23614*	.05887	.001	-.3970	-.0753
	Above 60 Years	1-20Years	.26019*	.06162	.000	.0918	.4286
		20-40 Years	.06256	.05810	.818	-.0962	.2213
		40-60 Years	.13618	.05492	.096	-.0139	.2863
		60 & Above	-.09996	.05757	.412	-.2573	.0574

Culture & Heritage	1-20 Years	2-40 Years	-.33511*	.07573	.000	-.5420	-.1282
		40-60 Years	-.14572	.07250	.262	-.3438	.0524
		60 & Above	-.30639*	.07519	.000	-.5119	-.1009
	20-40 Years	1-20 Years	.33511*	.07573	.000	.1282	.5420
		40-60Years	.18938*	.06852	.046	.0021	.3766
		60 & Above	.02871	.07136	.994	-.1663	.2237
	40-60Years	1-20Years	.14572	.07250	.262	-.0524	.3438
		20-40Years	-.18938*	.06852	.046	-.3766	-.0021
		60 & Above	-.16067	.06792	.126	-.3463	.0249
	Above 60 Years	1-20Years	.06129	.07109	.911	-.1330	.2556
		20-40 Years	-.27382*	.06703	.000	-.4570	-.0906
		40-60 Years	-.08443	.06336	.671	-.2576	.0887
Sustainability	1-20 Years	20-40Years	.11081	.05831	.318	-.0485	.2702
		40-60Years	.05947	.05583	.824	-.0931	.2120
		60 & Above	.23764*	.05790	.000	.0794	.3959
	20-40 Years	1-20Years	-.11081	.05831	.318	-.2702	.0485
		4-60Years	-.05134	.05276	.867	-.1955	.0928
		60 & Above	.12683	.05495	.143	-.0233	.2770
	40-60 Years	1-20Years	-.05947	.05583	.824	-.2120	.0931
		20-40 Years	.05134	.05276	.867	-.0928	.1955
		60 & Above	.17817*	.05230	.006	.0352	.3211
	Above 60 Years	1-20 Years	-.09717	.05474	.389	-.2468	.0524
		20-40 Years	.01364	.05161	.999	-.1274	.1547
		60 & Above	.14047*	.05115	.048	.0007	.2802

Source: Pilot Survey Data

Current study elucidates the significance of the differences of tourist sensitivity across gender and age groups of tourists. The differences are prominent and hence the Policy makers, private players and local community to join hands to be more sensitive for the development of good infrastructure facilities, preservation of culture and heritage (most importantly authenticity of culture) and sustainability practices to more eco-friendly, being sensitive to resources preservation and promotion of rich heritage.

CONCLUSION

Current research intends to ascertain the differences across demographical backgrounds with regard to tourists sensitivity (perceived perception) of Hampi as tourist destination. Tourist from different countries that visited the Hampi utsava were interviewed. Study

reveals that the differences of opinion exist for the three perspectives; Infrastructures, Culture & heritage and Sustainability across gender and age groups of tourists.

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The Evolution and Future Prospects of Solar Powered Electric Vehicles in Agriculture

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ABSTRACT

This work explains the development of solar-powered electric vehicles (EVs) adapted for agricultural applications such as seeding, weeding, and fertilizer spraying. Conventional farming rely on diesel-powered tractors, contributing significantly to fossil fuel consumption and environmental degradation, including acid rain and ecosystem disruption. Electric vehicles (EVs) have emerged as a promising solution, offering an environmentally friendly and energy-efficient mode of transportation. However, current EV designs are either unsuitable for agricultural tasks or dependent on grid-based charging, limiting their usability in remote rural areas. This paper reviews recent advancements and challenges in the integration of renewable energy—particularly solar—into agricultural EVs. It highlights the potential of intelligent control systems (ICS) and Maximum Power Point Tracking (MPPT) technologies to optimize energy use and improve vehicle performance. The study aims to present a comprehensive understanding of how a cost-effective, solar-powered EV model can be developed to enhance sustainability and efficiency in modern farming practices.

KEYWORDS : *Electric Vehicle (EV), MPPT (Maximum Power Point Tracking), Smart farming, Agricultural, BMS.*

INTRODUCTION

The use of solar-powered electric vehicles (EVs) in agriculture operations increases the efficiency of tasks such as seeding, weeding and pesticide spraying application. These vehicles provide a sustainable alternative to conventional diesel-fueled machinery, which is with significant environmental drawbacks. The benefits of incorporating solar-powered technology in associated agriculture are reducing carbon emissions and decreasing dependency on fossil fuels, thereby reducing soil acidification and ecological disruption. The shift towards electric mobility facilitates smoother operations, particularly in regions with abundant solar energy resources, contributing to a decrease in operational costs over time. With the growing demand for environmentally sustainable practices, solar-powered electric vehicles are solution for modernizing agricultural operations.

The use of traditional farming causes environmental degradation due to its dependence on fossil fuels. The combustion of these fuels results in greenhouse gas emissions and contributing to climate change and global warming. The use of diesel engines in agriculture leads to soil acidification, which impacts soil quality by altering its pH balance and reducing crop productivity (Ramkumar et al., 2024). The enormous uses of such machinery adversely affect plant and animal life. This necessitates a review of farming practices and solar-powered electric vehicles are an opportunity to reduce these detrimental effects by providing a cleaner and more sustainable alternative for agricultural operations.

The electric mobility offers a cleaner and more energy-efficient alternative to diesel-fueled machinery in agricultural use. By using solar power, these vehicles can use renewable energy, thus significantly reducing dependence on fossil fuels and minimizing greenhouse

gas emissions. This transformation to electric vehicles in agriculture not only reduces environmental pollution but also decreases energy consumption, promoting sustainable farming practices. The lower operating costs of electric vehicles enhance their desirability to farmers seeking to reduce expenses of farm operations (Ghobadpour et al., 2022). As electric vehicle technology progresses the agriculture industry is set to attain a harmonious equilibrium between productivity and environmental oversight, signaling a dramatic move towards sustainable agricultural practices.

Challenges and Innovations in Agricultural EVs

The challenges faced by electric vehicles (EVs) in agricultural field are the lack of sufficient charging infrastructure, particularly in off-grid rural areas. This limitation impedes large scale use of EVs, as farmers require reliable and convenient access to power to operate their machinery. Additionally, these regions experience technological gaps that worsen the difficulty of integrating new energy solutions (Ghobadpour et al., 2022). Another challenge involves the balance between energy storage capacity and vehicle weight, as increasing battery size to enhance range can adversely impact the operational efficiency of agricultural EVs. Nonetheless, ongoing innovations in energy management systems, such as intelligent control systems (ICS) and Maximum Power Point Tracking (MPPT), are paving the way for more effective solar energy harvesting, thereby improving the reliability and performance of agricultural EVs in these challenging environments.

The recent developments in solar photovoltaic (PV) systems are stimulating the evolution of electric vehicles for agricultural use by enhancing their efficiency and sustainability. Solar PV systems preferred for their abundant energy potential and are being adapted to meet the needs of modern agriculture, facilitating more

autonomous machinery operations (Gorjian et al., 2020). The integration of intelligent control systems (ICS) with these PV systems promises optimal energy management by dynamically adjusting power distribution according to real-time requirements. These systems, equipped with Maximum Power Point Tracking (MPPT) techniques, which boost energy extraction capabilities, allowing agricultural vehicles to operate efficiently even with variable solar intensity (Ramkumar et al., 2024).The integration between PV systems and advanced control technologies emphasizes a shift toward flexible and sustainable agricultural practices, and making less dependency from traditional fossil fuel and contributing to the eco-friendly technological integration in farming operations.

Features of Solar-Powered Smart EVs

- **Solar Integration:** The EV is equipped with solar panels which can harness energy from the sun, extending their operational range and reducing dependence on fossil fuel.
- **Electric Propulsion:** These electric vehicles uses sun energy as well as grid power (during absence of sun energy) produce zero emissions and contribute to a greener and more sustainable farming environment.
- **Intelligent Farming Systems:** Integrated with sensors and IoT technologies makes to perform tasks with precision.

LITERATURE SURVEY

The table below illustrates a literature survey of various papers based on their abstracts, detailing the motors and batteries employed in their respective works. Additionally, the survey covers energy sources, controllers, applications and limitations discussed in each paper.

Table 1.

Name of Authors, Paper Title and Year	Abstract	Motor And Battery	Energy Source, Control Er Unit, Application	Limitation Of Paper
Yang, 2024	Feasibility analysis of solar electric vehicles	Solar EV prototypes, DC-DC converters	Demonstrated solar EVs' environmental benefits and challenges like panel weight, range	Focused on road-going EVs; lacked agricultural contexts or terrain-adapted prototypes

Zahrawi & Aly, 2024	Comprehensive review of agrivoltaic systems	PV, crop integration, sustainability practices	Identified key challenges and strategies to enhance system durability and farmer acceptance	Lacked mobile EV integration; theoretical without field-tested prototypes
Anish, Rachcha, Arya Mishra, Kanchan Shinde "Smart Electric Tractor". 2022	A prototype was developed by the author featuring a smart electric steering mechanism, braking unit, electric powertrain, and chassis structure, prioritizing the use of IoT technology to enable intelligent automation and dynamic system control. In addition, analytical design evaluations will be carried out to optimize the powertrain for maximum performance and efficiency.	Induction Motor. Lithium Battery.	Grid power IOT Agriculture	The transmission system can be improved by integrating supplementary gear sets with ratios such as 15:1 or 10:1. However, this enhancement comes with the trade-off of increased charging duration and elevated overall costs.
Claudio Rossi , Davide Pontara , Carlo Falcomer , Marco Bertoldi and Riccardo Mandrioli "A Hybrid–Electric Driveline for Agricultural Tractors Based on an e-CVT Power-Split Transmission". 2021	This paper outlines the operational principle, structural design, and control approach of the proposed driveline system. Analysis of four potential operating modes reveals that the e-CVT driveline not only matches the performance of traditional tractors but also offers advanced functionalities such as power boost, full-electric mode, optimized auxiliary drive, and efficient electric power delivery..	DC Motor	ICE engine +Grid Power Agricultural (Four Wheel)	Despite utilizing hybrid electric technology, the vehicle still plays a role in greenhouse gas emissions and environmental degradation.

<p>Patel ashrafmusa, kasamjitaakeerSajid, khan ajazramzan, maknojiyasalmanyunus,obaidulHaqueAnsari “Electric Plough for Agriculture Using Bicycle”. 2021</p>	<p>The author designed and developed a cost-effective planter as an alternative to high- investment tractors, specifically to support small-scale farmers. Utilizing readily available and affordable components from a motorcycle, the frame was modified and transformed into a functional planter. A hub motor and battery system were integrated to power the machine. Since it operates on battery power, the planter offers an eco- friendly solution, significantly reducing air pollution and serving as a sustainable substitute for conventional, emission-producing tractors.</p>	<p>BLDC Hub-Motor of 36V, 250W LEAD-ACID</p>	<p>Grid Power MicroContro ller Agricultural (One Wheel)</p>	<p>The developed model is tailored for small-scale farming in confined agricultural plots and operates with a limited battery capacity. A single charge enables it to effectively cover an area of approximately 200 square feet, making it ideal for targeted cultivation in compact fields.</p>
<p>Swathi Kiran Kataboina1 , Mula Jagadeeswara Reddy1, Kalyan Dusarlapudi2” Multi-functional Electrical Vehicle for Agricultural Applications”2020</p>	<p>To address multiple challenges in agriculture, the author developed an electric agricultural vehicle designed to perform tasks such as weed detection, irrigation, crop protection, and pesticide spraying. The system integrates sensor technologies and IoT for intelligent control. Powered by both batteries and renewable energy sources, the vehicle offers a sustainable and cost- effective solution, specifically optimized for linear farming operations with enhanced reliability and efficiency.</p>	<p>DC motor LEAD-ACID</p>	<p>Solar Power, Grid Power Raspberry Pi, Arduino Agricultural</p>	<p>The system operates for a maximum duration of 45 minutes, making it unsuitable for large-scale agricultural applications.</p>

<p>Shweta Madiwalar, Dr. Sujata Patil, Sunita Meti, Nikhila Domanal, and Kaveri</p> <p>“A Survey on Solar-Powered Autonomous Multipurpose Agricultural Robot”. 2020 [05]</p>	<p>The author developed a low- cost, energy-efficient agricultural robot that significantly reduces human effort in farming operations. Broadly, such agricultural robots are utilized for tasks like harvesting, digging, cultivating, and planting. The primary objective of this robot is to ease the workload of farmers and enhance efficiency in small-scale agronomic activities..</p>	<p>DC Motor LEAD-ACID</p>	<p>Solar Power MSP430F55 29IPN, Agricultural (Four Wheels)</p>	<p>In the absence of solar energy, the functionality of solar-powered agricultural robots becomes compromised, rendering them inactive. Additionally, during seed dispensing tasks, the robot may deviate from its intended path. To address communication needs, Bluetooth wireless technology is integrated, enabling reliable short-range interaction between robotic units.</p>
<p>Diego Troncon, Luigi Alberti , Michele Mattetti “A feasibility study for agriculture tractors electrification: duty cycles simulation and consumption comparison”2019</p>	<p>The primary aim of the author is to demonstrate the viability of integrating hybrid tractors into modern agricultural practices. This study presents duty cycles and powertrain configurations relevant to agriculture, followed by a comparative analysis of fuel consumption and operational costs between conventional and hybrid tractors through simulation-based evaluation. As a foundational approach, the research emphasizes the advantages of utilizing full electric mode for light-duty operations, highlighting the effectiveness of advanced power management strategies in agricultural applications.</p>	<p>surface mounted permanent magnets (SPM) synchronous motor</p>	<p>ICE and Battery Matlab Simulink Agricultural</p>	<p>Functioning as a hybrid vehicle, the system is capable of smoothly switching to full electric mode, specifically optimized for performing light-duty agricultural tasks.</p>

OBJECTIVE

Based on the survey, the primary objective of this work is the design and development of a smart solar- powered electric vehicle for implementation in agricultural applications. It is having following advantages

- Avoids the dependency on fossil fuel as convention farming uses.
- Reduce the labour cost to do farming operations.
- It improve yield in field.
- To reduce greenhouse gasses and reduction of environmental pollution.

BLOCK DIAGRAM OF SYSTEM

The proposed system, is as shown in Figure 1.1, illustrate it integrates renewable energy utilization with electric mobility for agricultural applications. The methodology consists of following components.

PV Panels: Solar panel is mounted on the rooftop of the electric vehicle to extract maximum sun energy thought the day. It converts solar irradiations into electrical energy through the photovoltaic effect. Each panel consists of multiple photovoltaic cells connected in series and parallel combinations and it is made from silicon materials that generate electricity when exposed to sunlight.

Power Electronics (DC – DC Boost Conversion): It consists of Power electronics components such as DC-DC boost converters which increase the solar panel output voltage and also regulate the voltage to the stable level suitable for battery charging. Inverter convert the battery’s direct current (DC) into alternating current (AC) required operating the motor efficiently.

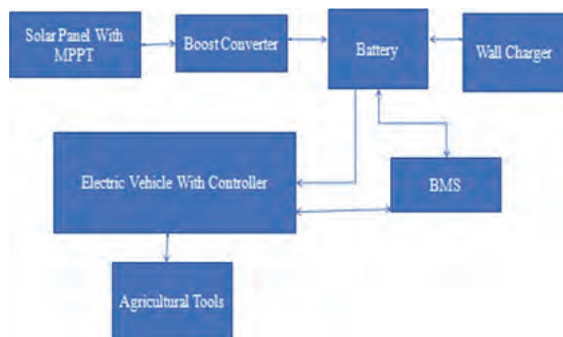


Fig. 1. Block diagram of model

Battery Pack: Battery is the main energy source for its propulsion. The battery pack consists of number of individual cells connected either in series or parallel to get required voltage level, which also store and deliver electrical energy. The boost converter charges a battery pack. Lithium-ion batteries are used due to their high energy density and efficiency.

Electric Motor: It converts stored electrical energy from battery into mechanical energy to run the vehicle. Depending on design requirements, both AC and DC motors may be used. A Brushless DC (BLDC) motor is used for vehicle propulsion due to its advantages such as high torque to weight ratio, low maintenance, silent operation and better control.

Battery Management System (BMS): A Battery Management System provides the safe operation of the battery pack by monitoring cell voltage, temperature and overall performance. It helps prevent overcharging, overheating and other conditions that reduces battery life or any damages takes place in battery.

Intelligent Control Unit (ICU): It acts as the central processing unit, which controls the various operations of electric vehicle. It minimizes energy use, controls drive functions, and ensures overall system efficiency and safety.

Dual Charging Capability (Wall Charger): In the absence of sun energy or during cloudy days the EV is charged by using grid power. The onboard charger facilitates the conversion of AC power from an external charging source into DC power for battery storage. This hybrid charging feature gives uninterrupted functionality.

Agricultural Tool Integration: The electric vehicle is designed with modular attachments to accommodate various agricultural tools such as seeders, weeders , pesticide sprayers etc. tools can be easily attached or detached based on the specific task .

Transportation: After field operations, agricultural tools can be removed and same EV can be used for transportation purpose.

MPPT Technique: The Maximum Power Point Tracking (MPPT) technique is implemented to optimize solar energy absorption throughout the day.

MPPT dynamically adjust the operating point of the solar panels to extract maximum power under changing environmental conditions.

Comparison of Proposed and Existing System

Table 2.

Feature	Proposed System	Conventional Tractor	Electric Vehicle (No Solar)
Fuel Cost	₹0 (solar)	₹300/day	₹80/day (charging)
CO ₂ Emissions	0	High	0
Operational Modes	Multi (Agri + Transport)	Agricultural only	Transport only
Charging Mode	Solar + Grid	NA	Grid only
Maintenance Cost	Low	High	Medium

BAR CHART INDICATING MAJOR MILESTONES

It's great to see that Figure 2 highlights the comparison between the use of tractors and electric vehicles (EVs) in agriculture. The advantages you've mentioned for using EVs in agriculture align with several potential benefits of transitioning from traditional combustion engine vehicles to electric ones in various sectors.

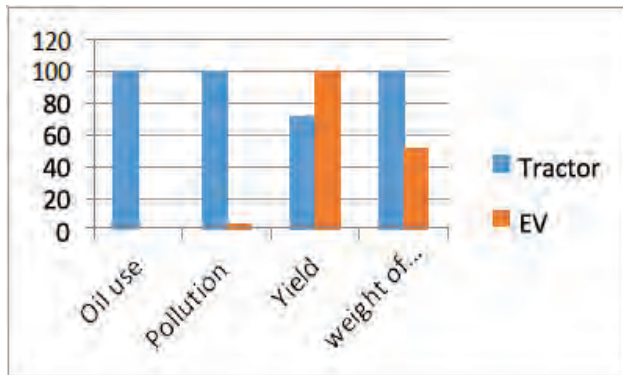


Fig. 2: Bar Chart of EV/Tractor

1. **Reduced Reliance on Fossil Fuels:** Electric vehicles operate using electricity, which can be sourced from renewable energy systems such as solar or wind. This transition supports energy diversification and

decreases dependency on petroleum-based fuels, fostering long-term sustainability in agriculture.

2. **Minimized Environmental Impact:** Since electric vehicles generate no tailpipe emissions, their use helps significantly lower air pollution levels, particularly in farming regions, thus contributing to healthier ecosystems and improved air quality.
3. **Lighter Vehicle Structure:** With a streamlined design and fewer mechanical components, electric vehicles typically weigh less than conventional machines. This reduction in weight enhances energy efficiency and lessens the compaction of agricultural soil, which is crucial for maintaining soil health.
4. **Reduced Operational and Maintenance Costs:** Thanks to fewer moving parts and lower maintenance requirements, electric vehicles offer cost-effective operation. This not only lowers long-term repair expenses but also reduces labor involvement in routine servicing.
5. **Enhanced Agricultural Productivity:** Integrating electric vehicles into farming operations can boost overall efficiency through precision-driven technologies. These advancements support better resource utilization and can directly lead to improved crop yields and optimized farm management.

CONCLUSION

The proposed work is concerned with the problems in the field of agriculture and generates solutions by designing and developing the multi-tasking Electric vehicle. Solar-powered Electric vehicle is a critical approach to dispose of trouble like air pollution and global warming and an opportunity for traditional gasoline-pushed motorcycles.

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Wireless Electric Vehicle Charging System

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ABSTRACT

For effective operation, electric vehicles need charging systems that are quick, affordable, and dependable. Systems for wireless charging eliminate the need for physical connections. Compared to traditional cable charging solutions, it is inconvenient to connect the device to be charged. Furthermore, because wireless charging eliminates the need for wires, mechanical connectors, and associated infrastructure, it is thought to be both environmentally benign and user-friendly. The fundamental architecture, working principles, and unique characteristics of wireless EV charging are presented in this study. The basic methods for wireless power transfer are first outlined and clarified. Electric vehicle wireless charging technologies are then categorized and thoroughly examined. The stationary as well as the Systems for dynamic wireless charging are studied and debated. Additionally, the Dynamic Wireless Charging System is a novel and distinctive approach. Dynamic charging systems aim to charge an electric vehicle (EV) while it is in motion and in use. The charging technology is based on magnetic linked resonant power transmission, which allows the transmitting coil to selectively turn on and off to charge cars while they are being driven. Because the transmission coil is ignited when the vehicle comes into contact with the receiving coil, energy is not squandered. The magnetic flux, a voltage is induced in the receiver coil when comes in line with transmitting coil. Control system functions of a wireless charging system of an electric vehicle. Findings of this state of the art review are discussed and recommendations for future research are also provided.

KEYWORDS : *Electric vehicle, Wireless charging, Dynamic charging, Arduino UNO, IR sensor.*

INTRODUCTION

The necessity for effective and sustainable charging options has been brought to light by the growing global usage of electric vehicles (EVs).

Despite their effectiveness, traditional cable charging stations have drawbacks such restricted accessibility, reliance on grid power, and user annoyance. With the ease of contactless power transmission and the potential for integration with renewable energy sources, wireless charging technology has emerged as a viable substitute to address these problems.

This project explores the development and deployment of an Arduino microcontroller- controlled wireless charging system for electric vehicles (EVs) that combines solar power with electromagnetic coils. The system's use of solar energy not only lessens dependency on traditional energy sources but also

encourages environmental sustainability. Wireless energy transmission by electromagnetic induction removes the need for physical connections, opening the door to more adaptable and convenient charging options.

An essential component of this system is the Arduino microprocessor, which offers precise control over power management, monitors solar panel energy input, and makes sure the electromagnetic coils are operating efficiently. The goal of this project is to provide a review of the future of sustainable EV infrastructure by proving that solar energy and wireless charging technologies can coexist.

The introduction of such a system could revolutionize the way EVs are charged, particularly in remote or off-grid locations where conventional charging infrastructure is limited. This project seeks to explore the potential of this innovative approach, laying the

groundwork for further development and real-world application of wireless EV charging systems powered by renewable energy.

METHODOLOGY & MODELING

if multiple charging stations are equipped with cable charging systems. There are more drawbacks to wired charging stations, including the need for greater space, a variety of socket types, a small substation, converter circuits installed at each charging station, a limited wire range, and longer charging times. The wireless electrical car charging method resolves all of these issues. Conventional plug-in or wired charging systems are not environmentally friendly or user friendly. Many batteries can be utilized to shorten the charging time, or the charged batteries can be switched out for the depleted ones as needed. Longterm coil conductivity results in energy waste via line loss. Its continual operation will short en its service life.

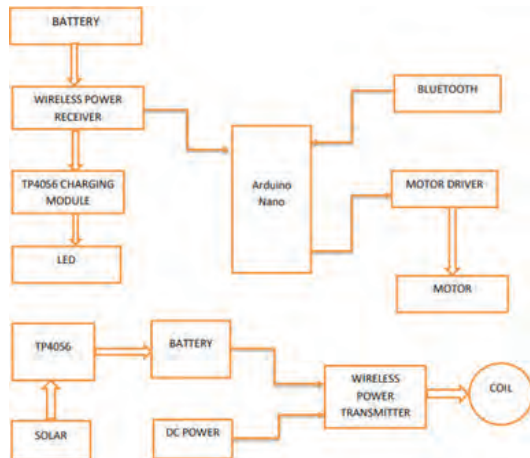


Fig. 1: Block Diagram of the project

Modelling

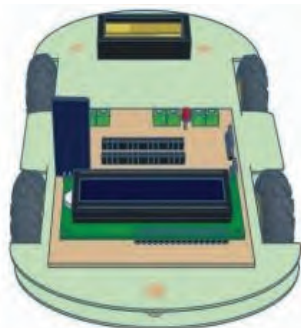


Fig. 2: 3D model of Vehicle

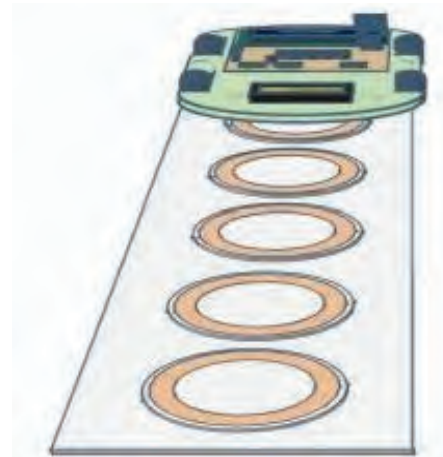


Fig. 3: 3D Prototype for Road Figure 3.3 illustrated the total project summary



Fig. 4: Receiving Coil

Figure 4 shows the coil situated beneath the prototypes vehicle design.

A three dimensional model was created in Fusion 360. The 3D model provides a detailed illustration of how the entire system is assembled. It covers every piece of hardware and component that is required, along with where those parts and equipment are located. Additionally, the hardware includes the project's moveable components. The car's components, which are arranged in a circle, are illuminated by an LED.

WIRELESS CHARGING ARCHITECTURE

The AC supply serves as the source of power for the transmission coil in a wireless charging system. The reception coil is linked using the resonant coupling concept. The output is sent to an ACDC converter,

which produces rectified DC for charging the load connected battery. Magnetic resonators are the coils utilized in the project that carry power wirelessly. This produces a magnetic field surrounding a transmission coil, aligns a receiving coil with the source's resonance frequency, This reaction is known as coupled magnetic response because it will couple resonance anywhere in that area, transforming the oscillating magnetic field into an electrical current inside the receiving coil.

A battery can be charged by feeding power to the load. Block schematic of wireless charging system is shown in Fig. 5 connected in series to series topology [6].

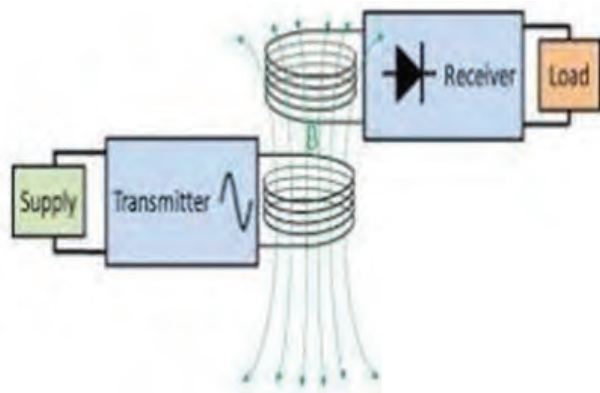


Fig. 5: Wireless Charging

Dynamic Wireless Power Transfer in Electric Vehicles

A force move system can be used by a hybrid or completely electric car to power the electric motor or charge the onboard Rechargeable Energy Storage System (RESS). The batteries can be charged using charging mats and a remote force move while stationary. Both alternatives are good for use whether doing an examination at home or while driving, but the car needs to be parked in a suitable location in order to charge the battery. We suggest an environmentally friendly wireless charging system for electric cars that enables wireless charging while the car is traveling on public highways. Vehicles are also charged using the suggested technique in parking lots, garages, and shopping centers. Furthermore, the wind turbines and solar PV systems positioned next to the roads might be used to provide electricity for the suggested charging infrastructure seen in figure 1.0. Micro grids are created by connecting renewable energy sources, such as wind

turbines and solar panels, to supply electricity for necessary services like wireless charging [8].

Streetlights can be powered by the excess energy, or it can be returned to the main power supply. The primary winding of an air-core transformer is buried in the road and its secondary, which is mounted on the vehicle, is also a component of the wireless battery charging system. Alternating current from the secondary is transformed into a voltage and current that may be utilized to charge the battery pack via a rectifier and dc converter stage.



Fig. 6: Prototype design of wireless transmission

HARDWARE TOOLS

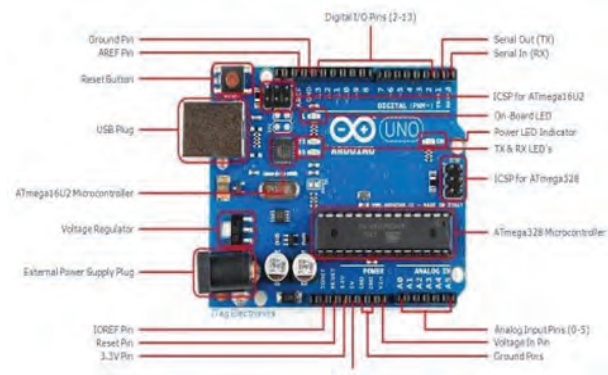


Fig. 7: Arduino Uno R3 Board

ARDUINO UNO- The Arduino Uno is the most popular version of Arduino. This board is what many individuals are discussing when they mention an Arduino. The Uno is among the most favored boards in the Arduino lineup and an excellent option for newcomers. Various revisions of the Arduino Uno exist, and the most recent one is detailed below (Rev3 or R3). The Arduino Uno is a microcontroller platform built on the ATmega328.

It features 14 digital I/O pins (with 6 functional as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB port, a power jack, an ICSP header, and a reset button. It has all the essentials to assist the microcontroller; just link it to a computer using a USB cable or power it with an AC-to-DC adapter or battery to begin

USB Plug & External Power Supply Plug

Each Arduino board requires a method to connect to a power supply. The Arduino Uno can be supplied with power via a USB cable connected to your computer or a wall adapter that ends in a barrel jack. The power supply is chosen automatically. The USB connection is also the method you'll use to upload code to your Arduino board. You can find information on programming with Arduino in my other post titled Installing and Programming Arduino. NOTE: The board can function with an external power source ranging from 6 to 20 volts. When provided with under 7V, the 5V pin could deliver less than five volts, causing instability in the board. Using more than 12V may lead to overheating of the voltage regulator, potentially damaging the board

Voltage Regulator

The voltage regulator isn't something you can (or should) engage with on the Arduino. However, it can be beneficial to be aware of its existence and its purpose. The voltage regulator performs its function by managing the level of voltage that enters the Arduino board. Consider it a sort of sentry; it will block any excess voltage that could damage the circuit. Certainly, it has restrictions, so avoid connecting your Arduino to anything exceeding 20 volts

Solar Panel



Solar panels are devices that convert sunlight into electricity, a process known as photovoltaic (PV) energy conversion. They are a critical component of renewable energy systems, helping to reduce reliance on fossil fuels and decrease greenhouse gas emissions.

Electromagnetic induction receiver coil



An Electromagnetic Induction Receiver Coil Module is a component used to detect and convert electromagnetic fields into electrical signals. It is often employed in wireless power transfer systems, RFID systems, or sensing applications. Here's a brief overview:

SOFTWARE TOOLS

Arduino IDE



Data types in C denote a comprehensive system utilized for defining variables or functions of various types. The nature of a variable dictates the amount of storage it uses and how the stored bit pattern is understood. The table below presents all the data types you will utilize in Arduino programming.

CONCLUSION

This project effectively illustrates the viability of an Arduino microcontroller controlled wireless charging system for electric vehicles (EVs) that are fueled by solar energy. A sustainable and effective way to charge EVs is to combine solar panels with electromagnetic coils, which solves a number of significant issues with conventional cable charging systems. The system is dependable and scalable thanks to the Arduino based control system, which guarantees accurate power management and operating efficiency.

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Design of a Bluetooth-Enabled Wireless Pulse Oximeter

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ABSTRACT

This test senior plan extend effective ly made a Bluetooth-enabled pulse oximeter utilizing the MAX 30100 and HC-05 modules utilizing Arduino NANO microcontroller. Precise sensor information was sent over the interface to a Android App, which was able to show the Oxygen Immersion (SpO2), and Heart Rate (HR) information. The come about imitated those that would have been gotten with a wired healing center oximeter, counting the waveforms and the precision of the information. This permits free development of patients inside their room and floor, facilitating the inconvenience clinic remain whereas still giving wellbeing checking. Clinics remain whereas sitlgiving wellbeing checking.

KEYWORDS : *Bluetooth (IEEE802.15.1), ZigBee (IEEE802 .15.4), MAX30100Pulse Oximeter sensor.*

INTRODUCTION

In today's world Remote Sensor Organize (WSN) innovation is exceptionally important subject that's worked on quite a number. WSN technology has parcels of broad usage region such as military, healthcare, mechanical and numerous more. Data can transferred one put to another or put away within the memory by means of WSN and therefore, they gotten to be well known within the sense of its unwavering quality, righteousness, low fetched and energy productivity. There are a few advance beneath the subject of Remote Sensor Network such as Bluetooth (IEEE802.15.1), ZigBee(IEEE802 .15.4), HomeRF, IrDA and Wireless Body Region Organize, WBANâIEEE802.15.6). Bluetooth could be a remote individual range organize standard which is created to provide brief remove application of transferring information. For the most part, it bolsters the data transmission in run of 10 meter long and in 2.4 GHz recurrence extend. Bluetooth has

broad utilization zone. such as domestic, vehicles, s shopping center office and numerous others. There are numerous applications which employments Bluetooth for information exchanging. For case, Setton, Guigner and Labidi examined abouts Bluetooth sensors for remote domestics and hospital healthcare checking[1]. In this consider, versatile and measured moo control platform was improved for wellbeing and life-style checking. The Bluetooth empowered sensors was utilized way of organize based administration in clinics or at domestics. MSP430 microcontroller manages slow control,flag handling, information capacity, LCD show an remote communication which was utilized for discrete estimation of blood pressure or ceaseless observing of wellbeing conditions of the patients for occurrence ECG and beat oximeter. Information was exchanged through the Web utilizing TCP IP or UDP conventions, and shows as web administrations. In conclusion, the development of genuine time.

LITERATURE SURVEYS

Presentation Beat ox meters are broadly utilized restorative gadgets for c hecking a patient’s blood oxygen immersion (SpO2) and heart rate. The Expanding request for in accessible healthcare rearrangements has driven to the improvement of remote beat oximeters coordinates with Bluetooth innovation. Bluetooth enabled gadgets offer consistent information exchange, compactness, and real-time checking, permitting for farther diagnostics and nonstop wellbeing following. This writing study investigates different thin ks about and advancements in the plan of Bluetooth-enabled wireless pulse oximeter.

Overview of Pulse Oximeters

A beat oximeter may be a noninvasive gadget utilized to degree the oxygen immersion of a patient’s blood and their beat rate. It works by radiating light through the skin and measuring the concentrated of light that’s either ingested or reflected by the blood vessels, which changes with the oxygenation level. The gadget calculates t h e p r o p o r t i o n o f ruddy the proportion of ruddy and infrared light retention to appraise SpO2.

METHODOLOGIES

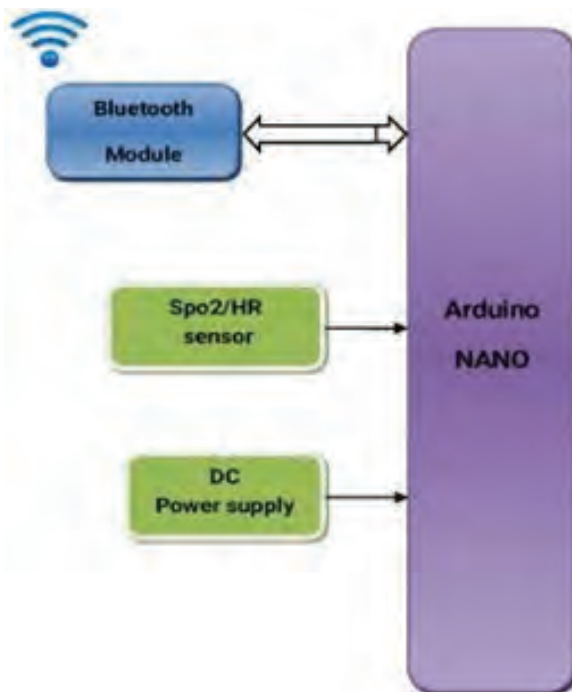


Fig: Bluetooth enabled wireless pulse oximeter

MAX30100Pulse Oximeter Sensor

MAX30100 Beat Oximeter Sensor with Arduino that can degree Blood Oxygen & Heart Rate and show it on 16x2 LCD Show. The blood Oxygen Concentration named as SpO2 is measured in Rate and Heart Beat/ Pulse Rate is measured in BPM. The MAX30100 may be a Beat Oximetry and heart rate screen sensor arrangement.

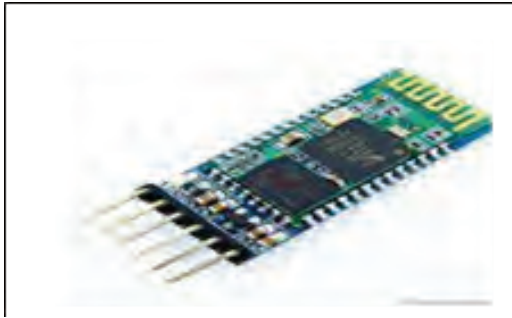


MAX30100	Arduino NANO
VIN	5V
GND	GND
SCL	A5
SDA	A4

Working of MAX30100Pulse Oximeter and Heart-Rate Sensor

The gadget has two LEDs, one transmitting ruddy light, another radiating infrared light. For beat rate, as it were the infrared light is required. Both the ruddy light and infrared light is used to measure oxygen levels within the blood. When the heart pumps blood, there’s an increment in oxygenated blood as a result of having more blood. As the heart unwinds, the volume of oxygenated blood also diminishes. By knowing the time between the increment and diminish of oxygenated blood, the beat rate is determined. It turns out, oxygenated blood retains more infrared light and passes more ruddy light whereas deoxygenated blood retains red light and passes more infrared light. Typically the primary work of the MAX30100: it peruses the assimilation level for both light source and put away them in a buffer that can be perused through I2C.

HC05 Bluetooth Module



HC-05 module is a simple to utilize Bluetooth SPP (Serial Harbour Convention) module, outlined for straight forward remote serial association setup. Serial harbour Bluetooth module is completely qualified Bluetooth V2.0+EDR (Enhanced Information Rate) 3Mbps Tweak with total 2.4GHz radio handset and baseband. It employs CSR Blue core 04-External single chip Bluetooth framework with CMOS technology and with AFH (Adaptive Recurrence Bouncing Include). It has the impression as little as 12.7mmx27mm. Hope it will simplify your generally design/development cycle.

WORKING

Since the MAX30100 as it were comes with the breakout board and the sensor on it, wires were fastened to the Vcc, GND, sda and scl lines as appeared in Figure 4. It was to begin with made in a graphing apparatus called Fritzing, and after that was actualized on the actual sensor. For less demanding dealing with and programming, at first an Arduino Uno board was used rather than the Arduino professional scaled down for testing the patched associations. The Uno is much bigger than the professional scaled down, and rather than patching wires it has simple get to plug-ins for wires, which made testing the sensor module quicker. A test program was run to initialize the sensor, examined values to the registers of the sensor and tests the communications between the board and the sensor. After initializing the sensor with the test program, the yield appeared underneath was gotten, which implied that the sensors was working accurately. After the victory of turning on the sensor and getting the over information, another test program was run to get Driven

readings from the sensor. After these tests, the sensor was fastened to the professional smaller than expected, associated to the HC-0 Bluetooth module and the information was effectively sent over a Bluetooth interface to a laptop computer.

CONCLUSION

This test plan of extend effectively made a Bluetooth-enabled pulse oximeter utilizing the MAX30100 and HC-05 modules. Exact sensor information was sent over the interface to a versatile app, which was able to show the, and data. The comes about mirrored those that would have been gotten with a wired healing center plus oximeter, counting the waveforms and the precision of the information. This permits free development of patients inside their room and floor, facilitating the distress of hospital remain whereas still giving wellbeing checking.

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A Remote Control Arduino Based Sprayer for Agricultural Pesticides

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ABSTRACT

Three-fourths of India's population lives in agricultural land. Farmers will cultivate a variety of plants in their field based on the climate and other resources at their disposal.

However, in order to attain high standards, some technical skills and technological support are needed. Output and superior quality. Extremely careful monitoring is part of the management of food crops, especially when it comes to treating illnesses that will have serious consequences after harvest. In crops, disease is defined as a change or deficiency in the normal functioning of the plant that results in specific symptoms. The primary definition of the disease that affects plants is any agent's pathogen. The majority of these pathogenic agent indicators are found in the crops' leaves, stems, and branches. Therefore, for plant cultivation to be effective and successful, disease identification and the percentage of illness produced in crops are essential. This can be accomplished by utilizing a camera to capture input photos and a machine learning technique to analyze them. This shows the disease that is present on the plant, leaf, or stem. In addition to predicting the remedies, this shows the diseased region and activates the pesticide sprayer, which applies the appropriate pesticide to the diseased area. This is crucial for the pesticide to be sprayed effectively. The Raspberry Pi3 serves as the processor or embedded system, while the L293d motor driver moves the robot. Python code is what we utilize for machine learning.

his uses preset photos to train the robot. The farmer will make money because this can be managed remotely without having to work in the field and be around pesticides.

His health problem will not impact him.

KEYWORDS : *Arduino, Raspberry Pi, IoT, ESP32, Servo motor, Relay.*

INTRODUCTION

Agriculture is the backbone of the global economy, giving millions of people access to food, raw materials, and a means of livelihood. However, conventional farming practices are usually labor-intensive and susceptible to inefficiencies caused by unknown plant diseases and inadequate use of resources. Early detection of plant diseases is crucial to maximizing crop yield and halting the spread of infections. Concurrently increasing agricultural productivity necessitates effective fertilizer, plowing, and planting methods. This project introduces a Leaf

Disease Detection[1] and Fertilizer Spraying Robot to boost agricultural output and reduce reliance on manual labor. The robot guarantees innovative, efficient, and expandable crop management. solution by combining IoT-enabled control with real-time disease diagnosis. A pesticide is a chemical that is used to eradicate, control, and destroy pests. However, farmers find that spraying pesticides is a very dangerous practice, therefore they want to exercise extreme caution by wearing appropriate clothing, gloves, masks, and other protective gear. We want to increase the crop. produce and stop harmful chemicals from endangering people. Long lances

or spray guns are employed to retain fluid at various goals in conventional techniques, which include hand-operated low and high quantity hydraulic sprayers and electricity-operated hydraulic sprayers with lengthy growth.

This method requires additional time and labor.

LITERATURE SURVEY

The author[1] has explained Bean leaves are susceptible to a variety of diseases, such as bean rust and angular leaf spots, which can cause significant damage to bean crops and lower their output. As a result, treating these conditions early on can improve the amount and quality of the product. In recent years, several robotic frameworks based on image and artificial intelligence Processing has been used to automatically treat a number of diseases..

The author [2] explores the development of autonomous systems for controlling agricultural pests and illnesses, with a focus on cotton and coffee crops. Coffee, a significant crop in the world, is threatened by pests like *Xylotrechus Quadripes* (Coffee White Stem Borer), which can cut harvests by as much as 70% southern India's mountainous regions.

The author[3] focuses on classifying and identifying diseases in the cotton region using image processing techniques. 79% of illnesses, such as *Alternaria*, *Bacterial Blight*, and *Myrothecium*, may be identified using machine learning-based categorization algorithms. Twenty per cent of the time, healthy leaves were incorrectly labelled as ill, and vice versa.

The author [4] described that in a variety of industries, the increasing demand for automated technologies has spurred the development of innovative solutions that increase speed, accuracy, and efficiency. The study draws attention to the challenges associated with conventional disease detection methods, which rely on eye inspection and may yield inaccurate and inconsistent results. To address this issue, the authors propose an autonomous robotic system that makes use of a CPU and a network of image sensors. The device uses voice control for mobility and ease, enabling it to navigate uneven fields or gardens.

This approach reduces the requirement for human

intervention by creatively fusing autonomous mobility with precise disease diagnosis. The results demonstrate how these systems can be applied to improve farming practices.

STATEMENT OF THE PROBLEM

For farmers, maintaining plant health and boosting agricultural yield are crucial challenges due to:

1. **Undetected Plant Diseases:** Due to their rapid spread and inability to be discovered until they have caused significant damage, many plant diseases result in significant output losses.
2. **Manual Labor Intensity:** Time-consuming and labor-intensive farming practices including fertilizing, sowing, and plowing are beyond the means of large-scale businesses.
3. **Ineffective Fertilizer Application:** Using too much or too little fertilizer can harm plants, deteriorate soil, and increase operational costs.
4. **Limited Technological Adoption:** Small and medium-sized farmers' ability to develop and be productive is usually constrained by their inability to purchase advanced machinery for automation and real-time disease diagnosis.

THE FOLLOWING ARE THE PROJECT'S MAIN GOALS

1. **Put Leaf Disease Detection into Practice:** With a Raspberry Pi and a camera, use machine learning-based image processing algorithms to detect plant illnesses in real time. Maximize
By including a relay-controlled pump system that will only apply fertilizer to unhealthy plants, resource usage can be reduced and waste can be avoided.
2. **Offer Control based on IoT:** Utilize an ESP32 microcontroller with the Blynk cloud platform to enable remote control and robot monitoring in both automated and manual modes.
3. **Precision spraying ensures that pesticides are only used where necessary by using AI-powered image recognition and sensors to identify pests, weeds, or crop diseases.**

4. **Decrease in Chemical Usage:** The technique reduces excessive pesticide application by focusing on particular locations, which lowers expenses and contamination in the environment.
5. **Environmental Protection – Precision spraying** reduces pesticide runoff into soil and water bodies, preserving ecosystems and biodiversity.
6. **Integration with IoT & Data Analytics – AI-powered sprayers** can collect and analyze data, helping farmers make informed decisions for future pest control strategies.
7. **Labor Reduction & Automation –** Reduces the need for manual labor by automating the pesticide application process, increasing efficiency.

PROPOSED METHODOLOGY

The suggested system integrates technologies including machine learning, embedded systems, and the Internet of Things (IoT) to build and deploy a leaf disease detection and fertilizer spraying robot. With the help of this technology, agricultural output will increase and labor costs will be decreased since it automatically detects leaf illnesses and applies fertilizer in real-time depending on plant health integrated with a solar-powered energy system. The system's two main components are an ESP32-based robotic platform for mobility management and basic agricultural tasks, and a Raspberry Pi-based image processing and disease detection system for controlling fertilizer application and monitoring plant health.

The ESP32-based robot can be operated in two different modes: Auto and Manual. In manual mode, users can use the Blynk app to control the robot's movements while using the L298N motor driver to steer four 60 RPM motors. It uses an ultrasonic sensor to detect obstructions and move autonomously when in auto mode. The robot also features a 1000 RPM crass-cutting motor that is activated by a relay. Additionally, the robot has two motors 10 RPM ploughs and a servo motor for automatic seed sowing.

On the other hand, the Raspberry Pi is responsible for identifying leaf disease. The images of the plant leaves captured by a USB camera are processed by a trained Convolutional Neural Network (CNN) model.

This model is trained using a dataset of both healthy and sick people in order to identify any patterns of illness sickly leaves. Every time a disease is identified, the device uses a relay to activate a pump that applies fertilizer to the affected area. This system combines machine learning techniques, ESP32, Raspberry Pi,[4] and the Blynk software to provide an efficient solution for modern farming. It is a dependable, cost-effective precision agricultural device that improves plant health monitoring and reduces human labor

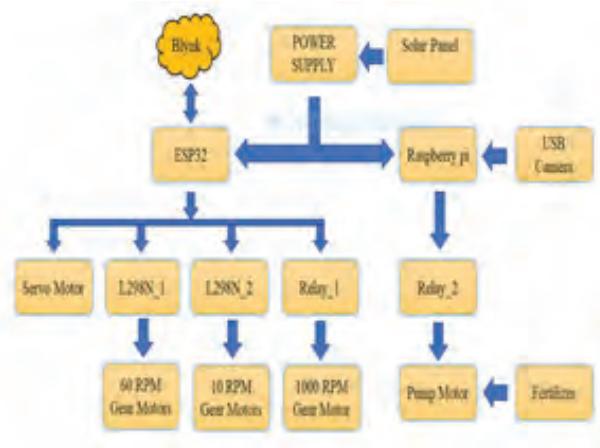


Fig. 1: Block diagram

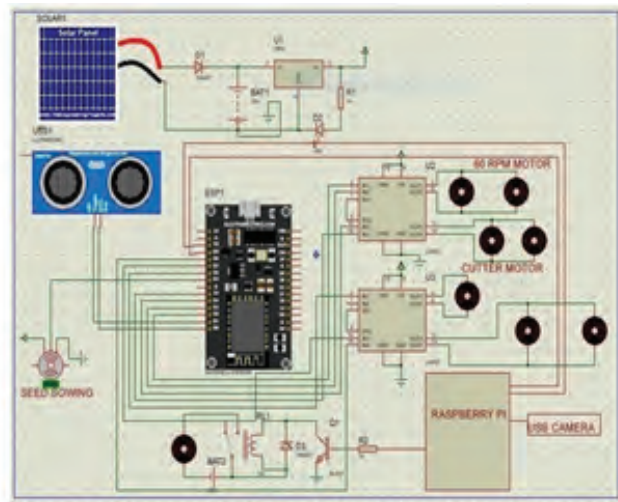


Fig. 2: Circuit diagram

RESULT AND DISCUSSION

The Leaf Disease Detection and Fertilizer Spraying Robot was successfully designed, put into use, and tested to evaluate its performance in both manual

and autonomous modes. The results demonstrate how effectively the system handles agricultural tasks like plowing, diagnosing leaf diseases, fertilizer application and seeding.



Fig. 3: Designed Model

The ESP32-based robotic platform's navigation and task-execution capabilities were assessed. In manual mode, which was managed by the Blynk app, the robot could move precisely in all four directions using the 60 RPM motors. The control interface of the Blynk app was quick and simple to use, enabling smooth operation. In Auto mode, the ultrasonic sensor successfully detected obstacles, ensuring secure travel. The trash cutting apparatus with a 1000 RPM motor effectively cleaned the plant's surroundings during testing. The plowing setup, which was driven by two 10 RPM motors, demonstrated consistent soil preparation. The seed-sowing apparatus powered by a servo motor generated accurate and reliable seed placement. The robot's application in agricultural environments was enhanced by each of these features. The table 1 shows the comparison of traditional agriculture and use of pesticide spraying robot in agriculture.

The Raspberry Pi-based disease detection system accurately identified leaf ailments using the trained Convolution Neural Network (CNN) model. The model successfully differentiated between healthy and ill leaves by analyzing test photographs captured in real time by

the camera via USB. The fertilizer spraying relay and pump system promptly activated upon detecting a sick plant, ensuring focused treatment. The trained CNN model showed outstanding accuracy with performance metrics like precision, recall, and F1-score indicating reliable sickness identification. The integration of the Raspberry Pi and ESP32 components through IoT connectivity allowed the system to function more seamlessly. The Blynk cloud provided real-time updates and control, which enhanced accessibility and user experience. The table 2 shows the relationship between crop monitoring and disease detection in agriculture.

Table 1. Relationship between Crop Monitoring and Disease Detection in Agriculture [5]

Aspect	Crop monitoring method	Disease detection ad benefits
Visual inspection	Regular field visit	Early identification of visual symptoms
	Observation of plant health	Prompt action to contain and manage disease
	Scouting for abnormalities	Reduced spread, minimizing yield loss
Sensor technology	Solar moisture sensor	It detect the soil moisture using of sensor
	Weather stations	It detects the air and provide the solution
	Plant health sensors	Detection of subtle changes in crop health
Weather and environmental	Real time weather data	Correlation environmental conditions it disease risk
	Climate modeling	Early warning systems for disease outbreaks
Smart phone apps	Image recognition app	On the go diseases identification and reporting
Raspberry pi	Trained convolution neural network	Identification of leaf disease

Data analysis	GPS based fields mapping	Efficient data collection and sharing among farmers
	Machine learning algorithms	Predictive model for diseases outbreak forecasting
	Statistical analysis	Decisions supports for disease management

ADVANTAGES

1. They can function with greater tolerances, lowering direct exposure to pesticides and the human body while increasing production efficiency.
2. They operate faster and make fewer errors, and the machines are able to accurately identify higher-quality products.
3. Up to 30% less herbicide is used on farms thanks to the robots.
4. For people who must construct and fix them, robots could lead to new employment opportunities.

DISADVANTAGES

1. Time-Consuming: Mechanical tool operation and inspection by hand take a lot of time and effort, which makes them unsuitable for large-scale farming.
2. Lack of Precision: Human error can lead to erroneous judgments and postponed actions when disease detection is done by hand observation.
3. Resource Wastage: Excessive use of water, herbicides, and fertilizers is frequently caused by mechanical tools and stand-alone systems, raising expenses and damaging the environment.
4. Limited Integration: Current approaches are task-specific and do not provide a comprehensive solution for automation, fertilization, and disease detection.
5. High Dependency on Labor: Human labor is a major component of traditional systems, although it may be erratic and challenging to coordinate at busy times or labor shortages.

6. Scalability Challenges: These techniques' application to small-scale farms is limited since they cannot be scaled to satisfy the demands of contemporary, large-scale farming operations

CONCLUSION

The development of the Leaf Disease Detection and Fertilizer Spraying Robot is a good example of the potential of integrating IoT, machine learning, and renewable energy for precision agriculture. Combining innovative elements such as multipurpose agriculture practices,

The robot provides a practical and sustainable solution to today's farming issues with its automated illness diagnosis and targeted fertilizer spraying. Navigation and task execution are effectively managed by the ESP32-based robotic platform, which has both manual and autonomous operating modes. In manual mode, users can control the robot remotely via the Blynk app, while in auto mode, an ultrasonic sensor is used for obstacle detection and navigation. The addition of tools for plowing, sowing, and root cutting increases the robot's versatility even more. The servo-controlled seed sowing and two 10 RPM ploughing motors ran consistently, ensuring consistent operation during testing. The Raspberry Pi-based leaf disease detection system used a trained Convolution Neural Network (CNN) to accurately identify diseased plants based on real-time photographs captured with a USB camera. The fertilizer spraying system was automatically triggered upon disease detection to ensure precise and efficient treatment, reduce chemical waste, and improve plant health monitoring. Performance metrics including accuracy and recall validated the model's effectiveness. Because the system uses a solar panel, which provides a renewable energy source, it is suitable for installation in locations with limited access to electricity and is environmentally friendly. This feature reduces the robot's dependence on outside power sources while enhancing its sustainability and operational effectiveness.

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Concept of usage of Piezoelectric Ceramic PZT5H materials in the Suspension System of Electric Vehicles to Produce Electricity

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ABSTRACT

Usage of the dynamic compression stress on Macpherson strut by transferring it to PZT5H piezoelectric ceramic discs and produce electricity to minimize the load on electric vehicle battery. Hence the energy losses due to forces acting on suspension struts will be converted to electrical energy.

KEYWORDS : Piezoelectric, PZT5H, Macpherson suspension system, Electrical vehicle, Battery, Compression stress

INTRODUCTION

The piezoelectric material is the material, which produces the electric energy when subjected to mechanical stress, using this principle the electricity can be generated by inserting the PZT5H piezoelectric ceramic discs on the each Macpherson struts of suspension of electric vehicle and these discs will be subjected high frequency stresses and the sufficient voltage(AC electrical energy) can be generated it can be either utilized for charging the batteries of EV or operate the accessories of Electric Vehicle in run time.

MECHANISM OF SYSTEM

1. The piezoelectric ceramic material PZT5H discs on the top of Macpherson struts of electric vehicles suspension. The shocks of the suspension system will be absorbed by the struts and then transferred to the PZT5H and it converts that high shocks of high frequency will produce the high AC voltage and this AC voltage will be converted to DC voltage by using proper rectifiers.
2. Material selection:- PZT-5H is suitable to absorb the compression loads up to 800 kg per cm sq. (60Mpa under quasi static condition and 150Mpa

under dynamic compression) the PZT5H has a properties to withstand high temperature up to 180 degree Celsius and has good piezoelectric voltage constant of 0.029Volt meter Newton.

3. The PZT5H can also be inserted in the spring buffer kit to utilize the shocks of coil springs of vehicles for producing voltage in the PZT5H.

CALCULATION OF APPROXIMATE VOLTAGE GENERATED FROM THE PZT5H

Consider an approximate mass of an electric hatchback car will be around 2000kg the Weight of the same will be, $F=ma$ $F= 2000*9.8= 19600N$ since the hatchback has the four wheels the force will be distributed evenly on the wheels hence the each wheel absorbs the force of $19600/4= 4900 N$.

The formula for calculating the electric field produced is $E=g*F/A$, where 'g' is Piezoelectric voltage constant and 'F' is force acting on the disc and 'A' is Area of piezoelectric disc subjected to force F. Considering the disc of 15cm diameter and 14mm thickness PZT5H piezoelectric material is as follows. And the force of

about 4900N applied on each disc, the resulting electric field will be calculated as follows.

PZT5H Piezoelectric voltage constant $g=0.029 \text{ Vm/N}$,
 $F= 4900 \text{ N}$ and thickness of piezoelectric disc is $d=0.014\text{m}$

The electric field $E=g*F/A$

$$E=0.029*4900/0.0176=8073.86\text{V/m}$$

Hence

$$\text{generated Electric field } E=8073.86 \text{ V/m}$$

The voltage produced by this electric field is $V=Ed$ where 'E' is electric field produced and 'd' is the distance between the two points that is the distance between the two faces of disc subjected to force and it is equal to the thickness of the disc.

$$V=8073.86*0.014=113.10 \text{ Volts}$$

Since there are four wheels, each wheel will generate voltage of approximately 113 Volts. And connecting them in series, the whole system can get the voltage of around 440 Volts and it will be sufficient for charging EV battery in the run time. And also the circuit can be switched over to parallel connection to get the voltage of 220V can be utilized to run accessories of EV.

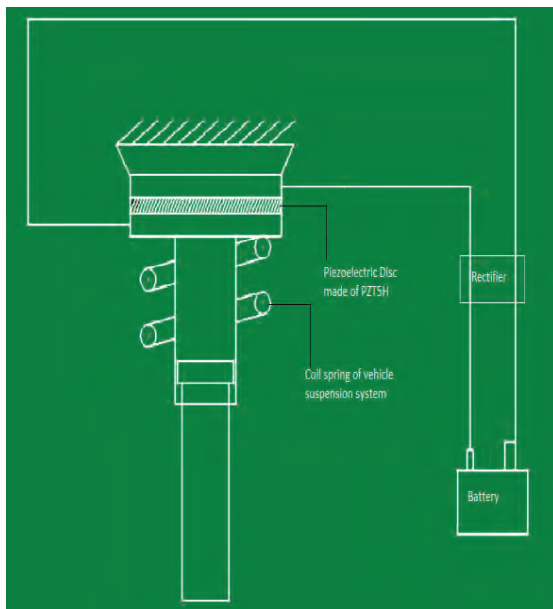


Figure 1. Shows the schematic representation of concept of producing electricity by installing the PZT5H discs above Macpherson strut of vehicles suspension system

ADVANTAGES

This system is very useful for suburban and rural roads as the vehicle wheels are always subjected to continuous shocks and this makes the system generate the electric voltage for consumption and battery charging purpose for the electric vehicle. The life span of PZT5H is about 15 to 20 years. So the PZT5H discs can be changed over the period of 15 years. The added advantages are increase in the ground clearance of vehicle.

DISADVANTAGES

This system needs to reduce length of Mac person strut to match the original ground clearance keeping the stability of vehicle at very high speed.

CONCLUSION

The system will increase the efficiency of electric vehicles and boosts the usage of piezoelectricity by minimizing the energy loss.

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Heart Attack Detection and Heart Rate Monitoring

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ABSTRACT

The Internet of Things (IoT) is entombing correspondence of installed gadgets utilizing organizing advancements. The IoT will be one of the significant patterns in future; can influence the systems administration, business and correspondence. Right now, a remote detecting parameter of the human body which comprises of heartbeat and temperature. The parameters that are utilized for detecting and observing will send the information through remote sensors. Including an online watching assist with monitoring the standard well-being status of a patient. The detecting information will be consistently gathered in a database and will be utilized to advise patient to any inconspicuous issues to experience conceivable conclusion. Trial results demonstrate the proposed framework is easy to understand, solid, affordable.

KEYWORDS : *IoT, Remote sensors, Parameters, Detecting information, Monitoring.*

INTRODUCTION

In this project, we are monitoring various patient parameters via the Internet of Things. In the patient monitoring system based on the Internet of Things project, real-time parameters of the patient's health status are sent to the cloud via the Internet connection. These settings are sent to a remote Internet location so that the user can see these details from anywhere in the world. Another advantage of using IOT is that this data can be viewed on a desktop computer, a laptop and an Android smartphone [1]. The user only needs a working internet connection to view this data. There are several cloud service providers with which this data can be viewed on the Internet. Although most elderly and disabled people prefer to live at home, their activities and health should be constantly monitored so that immediate help can be provided. Smart homes can be described as technologically advanced homes that allow automation of household chores, easier communication, and greater security. Smart homes can significantly improve the lives of seniors and people with disabilities by being able to stay in their homes

where they feel more comfortable. Because smart homes are tailored to the specific needs of the elderly and disabled, they can help service providers improve the quality of services provided in many ways. Smart home systems can generally be installed and maintained in residential environments without complexity [2]. They can be implemented with different visible and/or almost invisible components with different functions. In most cases, invisible components increase acceptance of the use of the intelligent home automation system in a domestic environment. Smart home functions are typically based on a network of wireless sensors. The wireless sensor network consists of a series of distributed sensor nodes that are used in the environment to measure physiological parameters. At the hardware level, the wireless sensor network is generally in the form of a star topology and a central coordinator of sensor nodes collects data from sensors connected to various devices [3]. As the wireless sensor network collects data on the activity of the person being monitored, it detects the activities of daily life and the lifestyle of elderly and disabled people who live alone. The activity-based

model allows elderly monitoring and to predict any unusual behavior of the person to be monitored using the predicting and analysis model obtained from regular and irregular activity from sensors.

LITERATURE REVIEW

Several researchers have explored the integration of IoT, wearable sensors, and embedded systems for healthcare monitoring and robotic applications. Manisha et al. [1] and Yadav and Gowda [4] focused on IoT and wearable-based heart rate monitoring systems capable of detecting heart attack conditions in real time, emphasizing continuous patient monitoring and remote data access. Malik and Pathro [7] further demonstrated heart rate measurement using fingertip sensors interfaced with Arduino, highlighting low-cost and efficient physiological monitoring solutions. Patel and Chouhan [5] introduced a motion-sensing approach using the Kinect device to detect abnormal patient behaviour and trigger medical assistance during emergency situations. In the area of robotic systems, Sundari and Sivaguru [2] presented the design and implementation of an IoT-enabled robotic arm, enabling remote operation and monitoring, while Seeni et al. [3] extended this concept by developing an IoT-based robotic arm specifically for healthcare applications. Additionally, Thavamani et al. [6] analysed the simulation and modelling of a 6-DOF robotic manipulator using MATLAB, contributing to improved robotic control and precision. Sundari [8] also proposed an embedded-system-based solution for estimating hearing loss using an interactive pure tone audiometric test, demonstrating the versatility of embedded and IoT technologies in medical diagnostics. Collectively, these studies highlight the growing role of IoT, wearable devices, and robotic systems in enhancing healthcare monitoring, diagnostics, and patient assistance.

METHODOLOGY

Hardware configuration: Using the Max10300, attach the heart rate sensor to the ESP32 Node MCU. To ensure appropriate communication between the devices, make sure to inspect the wiring and connections. Data gathering Get information about the user's heart rate using the heart rate sensor. To collect data at regular on a sensor a finger on a button, or a Twitter post - and

convert them into outputs like as operating a motor, turning on an LED, and publishing anything online intervals and store it in the ESP32's memory, you can define a sample rate. Processing of signals Once the data is gathered, it must be processed in order to extract useful features for heart attack detection. Filter, segment, and analyse the signal using the proper methods to extract important information such as heart rate variability, QT intervals, etc. recognising a heart attack: Use a machine learning algorithm to categories the signal as a normal or abnormal heartbeat after the features have been collected. To ensure accurate detection, the machine learning model can be trained on a dataset of normal and abnormal heart beats Real-time monitoring: After the system is created, it may be used to track the user's heart rate in real-time. If an aberrant heart rate is found, the system can notify the user so that immediate medical treatment can be sought. Finally, you can visualize the heart rate data gathered over time using a dashboard or a mobile application. This can be used to track the user's heart rate trends and spot any anomalies for both the user and medical specialists.

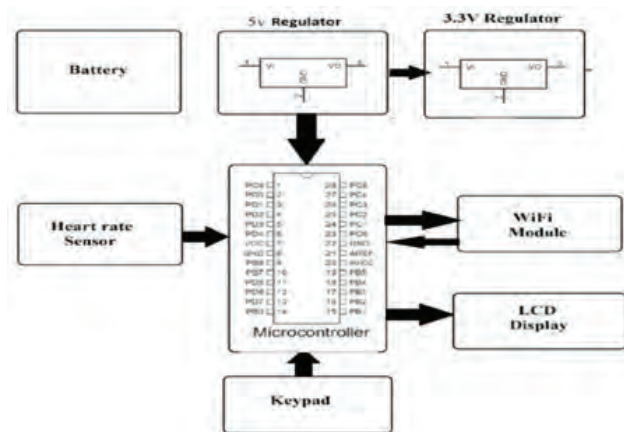


Fig. 1. Block diagram

SYSTEM DESIGN

The overall design of the system is explained through the block diagram shown below. It describes all the components needed to implement a system. Figure 1 shows the block diagram of A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers to display information. Liquid crystals do not emit light

directly but instead use a backlight or reflector to produce images in colour or monochrome.

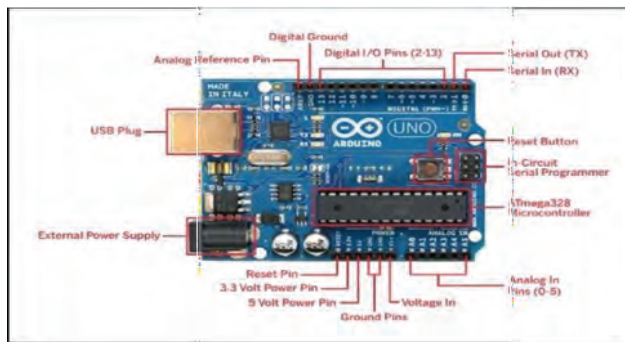


Fig. 2. Arduino UNO

LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden: preset words, digits, and seven-segment displays (as in a digital clock) are all examples of devices with these displays. They use the same basic technology, except that arbitrary images are made from a matrix of small pixels, while other displays have larger elements.



Fig. 3. LCD Display

Here a thermistor is used as the temperature sensor. Temperature sensors measure the amount of thermal energy, or even cold, generated by an object or system, and allow us to "capture" or capture the physical changes in that temperature, producing analog or digital output [8]. Here a NTC type thermistor is used which has its output resistance reduced with increase in temperature.



Fig. 4. Temperature sensor

Heart rate monitors are devices that detect and measure your heart or pulse rate. Thanks to advances in technology, these devices are small, wearable and many use sensors that are very accurate. However, while these devices are excellent for personal use, they're no substitute for medical devices that are much more accurate.

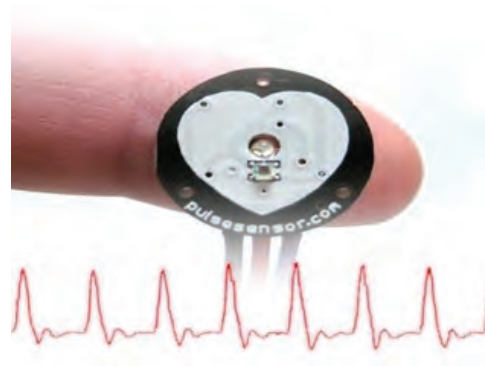


Fig. 5. Heart rate monitor

PROPOSED FRAMEWORK

The hardware design is implemented using an Arduino microcontroller board. The vital sensors were connected to the IOs of the board which senses the physical parameters of the elderly person and sends signal to arguing. Output of the hardware provides real time monitoring of physical health conditions such as the pulse rate, body temperature and stress are displayed in LCD module.

The project's central premise is to allow users to prepay for electricity and automatically monitor energy consumption, while also detecting and alerting to electricity theft.

RESULT AND DISCUSSION

Smart home systems for monitoring the elderly aims to collect real-time information based on the daily activity level of the people monitored and thereby learn to recognize their personal patterns. If these monitored models deviate from the standard models, smart home systems alert caregivers and family members and let them take immediate action.

CONCLUSION

In this system, a heart attack can be recognized using IoT and lives can be saved. This system helps

elderly people who have heart problems more often. In addition to the heart rate, this system can also measure blood pressure. Doctors or others are informed of the heart attack using an alert system. Thus, this system ensures the safety of the elderly persons by assisting and monitoring their health and also personal safe. The system is cost-effective, user-friendly, and secure, making it ideal for modern energy management in home and business environment.

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NeuroFlex - A Smart Glove Rehabilitation Device for Parkinson's Disease

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ABSTRACT

Over the past decade, significant papers have shown that rehabilitation exercise is efficient in enhancing Parkinson's disease efficiency. However, the previous devices in Parkinson Disease Rehabilitation are not very efficient as they are far too complicated, heavy in size, and difficult to conduct. This paper will focus on developing a smart rehabilitation hand device prototype using an Arduino micro controller, to control the soft actuator by using pneumatic system and IOT system for the individual with Parkinson's disease. The actuators are designed mechanically to match and support the human finger range as it features a light weight structure, simplistic design, cost-effective and safer to use compared to other conventional actuators. A soft actuator, accelerometer sensor, pneumatic air valve and Arduino Mega were designed as a control hardware system to operate the smart rehabilitation glove. Therefore, this study will focus on obtaining data results based on the length of the single actuator, the bending angle of the actuator based on the applied pressure, the hand position of the accelerometer sensor based on the x, y, z-axis and the suitable pressure for the SGRD rehabilitation system for future research purposes. This prototype will assist the subject's hand movement by improving the subject quality in helping the patient with Parkinson's disorder recover.

KEYWORDS : *Arduino mega, IoT system, Pneumatic system, Soft actuator, Accelerometer sensor, Pneumatic air valve, Control hardware system.*

INTRODUCTION

Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects millions worldwide, primarily impacting motor function. As the global population ages, the incidence of PD is expected to double over the next three decades. This condition is characterized by reduced dopamine production in the substantia nigra, leading to symptoms such as tremors, muscle rigidity, slow movements, and impaired balance. Rehabilitation is critical for improving and maintaining motor abilities in patients with PD. Strength training, physiotherapy, and occupational therapy have shown measurable benefits in improving mobility and delaying disease progression. However, traditional rehabilitation

approaches often require in-person therapy sessions, which may be difficult for many patients to access regularly. This Paper presents the design and development of a Smart Glove Rehabilitation Device (SGRD), a wearable system intended to assist finger movement using soft pneumatic actuators controlled by an Arduino Mega 2560 microcontroller. The glove integrates an accelerometer sensor to capture hand gestures and provides IoT connectivity, allowing real-time monitoring and control of therapy sessions remotely.

Unlike existing commercial devices such as the Bravo Hand or Haptic Hand, which are often heavy, complex, and expensive, the proposed SGRD offers a

lightweight, user-friendly, and cost-effective solution. The soft actuators are designed to match the natural motion of human fingers, providing safe and controlled assistance for hand opening and closing. The glove is structured using breathable material for comfort and can be used daily without professional supervision. This paper focuses on the mechanical design, hardware integration, and software control logic of the SGRD system, includes measuring the bending angle of the actuators, evaluating the response of the accelerometer, and determining the optimal pressure levels for effective finger movement assistance. The outcomes of this work aim to contribute to the advancement of smart rehabilitation technologies by offering an accessible tool for home-based motor recovery.

LITERATURE REVIEW

1. The study by Al-Fahaam et al. (2019) presents the development of a wearable soft robotic glove aimed at aiding post-stroke rehabilitation.

The glove is designed to assist in the recovery of hand functions through a combination of soft robotics and wearable technology. It incorporates flexible actuators and sensors to facilitate natural movement and provide real-time feedback for both the patient and the therapist. The system allows for personalized therapy sessions tailored to the patient's needs, promoting improved hand mobility and strength. The researchers emphasize the glove's potential to enhance rehabilitation outcomes by enabling repetitive, controlled exercises that are crucial for neuro plasticity and functional recovery.

2. Chen et al. (2020) introduce an IoT-based smart rehabilitation system designed for home use, aiming to make rehabilitation more accessible and efficient for patients.

The system integrates wearable sensors, communication devices, and a user-friendly interface to monitor patients' exercises and vital signs remotely. Real-time data is transmitted to healthcare professionals, enabling them to track patient progress, make informed adjustments to therapy plans, and intervene as needed. The study highlights how this IoT-based approach supports personalized rehabilitation, continuous monitoring, and patient empowerment by allowing therapy outside clinical settings, ultimately enhancing convenience and patient compliance.

3. O'Connell et al. (2019) investigated the role of technology in engaging patients during stroke rehabilitation.

The study analyzed various technological interventions, including wearable devices, virtual reality systems, and mobile apps, aimed at increasing patient participation and motivation. The findings indicated that technology-driven rehabilitation tools could provide immersive and interactive experiences, making therapy more engaging and less monotonous. By offering real-time feedback, gamification elements, and personalized exercise plans, these technologies helped patients stay committed to their recovery process.

4. Pistohl et al. (2019) examined user acceptance and accessibility of wearable and robotic technologies in assistive and rehabilitation therapy.

The study focused on how patients and healthcare providers perceive the usability and effectiveness of these technologies in promoting rehabilitation. It found that while these devices hold great potential for improving patient outcomes, factors such as ease of use, comfort, and affordability significantly influence their acceptance. The research highlighted the importance of user-friendly designs and customization to meet individual needs.

METHODOLOGY

Prosthetic Hand Design

The hand is designed using Solid Works Computer Aided Design (CAD) software. Solid Works is utilized because of easy to use and operate. The solid model of prosthetic hand design can be exported into Sim Mechanics model for 3D animation and kinematics analysis purposes.

The 3D CAD model of the prosthetic hand cover can be seen in Fig. 1. In order to the proposed of prosthetic hand has the same size and weight with the natural human hand, all of mechatronics component has are designed to fit into the hand.

After the 3D model is developed in Solid Works, the model needs to be printed using 3D printer. The hand is made from PLA (Polylactic Acid) material. The material is selected due to lightweight property. The 3D hand model of this prosthetic hand is inspired by Ada Hand from Open Bionics.

The size of the prosthetic hand is 180 mm in length, 85 mm in width, and 50 mm in thick. The overall mass of the prosthetic hand is 261 grams. The size, shape, and weight of the prosthetic hand approach with the human natural hand. This is very lightweight prosthetic hand, when the user/trans-radial amputee used it as prosthetic hand, the user can manipulate object grasping task without feels fatigue. The general characteristics comparison of Asto Hand v1.0 can be summarized in Table 2. Based on the Table II, the mass of available robotic hand varies from 261 gr to 760 gr.



Fig. 1. Robotic Arm

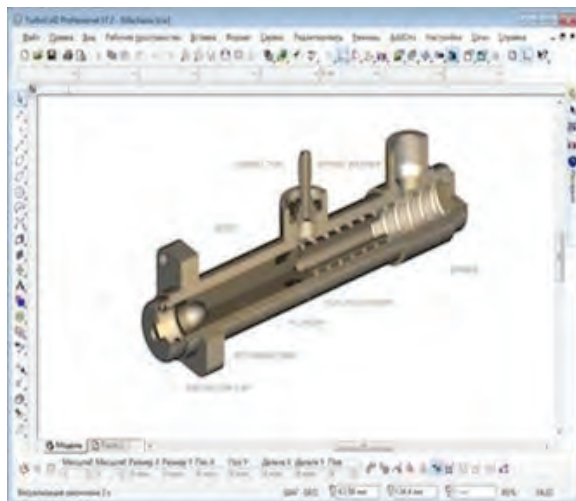


Fig. 2. Mechanical Drawing

Hardware Implementation

The electronic part of the SGRD rehabilitation device is an essential part of the rehabilitation device. The schematic diagrams of electrical component were

design using Fritzing Software, which allows the user to construct a real circuit from the library part to make connections. Fig 3 below indicates the block diagram for the SGRD operation which consist of Arduino Mega 2560 as the micro controller that is connected with other components.

The electronic circuit connections consist of an accelerometer sensor, four Channel 5v relay module, 5v valve and esp8266 Wi-Fi module.

The system is supplied from the 5v power supply to ON the Arduino Mega for data acquisition and testing purposes. The system consists of four valves actuators which are been controlled with a relay module.

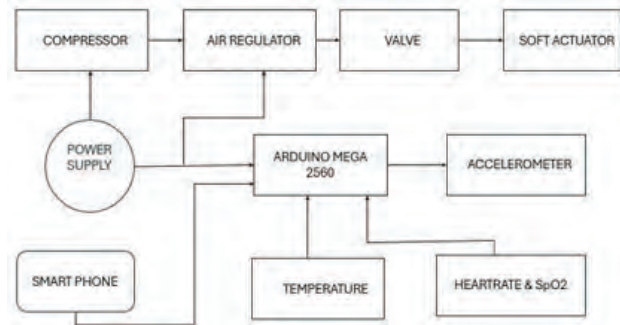


Fig. 3. Block Diagram

The above figure indicates the block diagram for the SGRD operation which consist of Arduino Mega 2560 as the micro controller that is connected with other components. The electronic circuit connections consist of an accelerometer sensor, four Channel 5v relay module, 5v valve and esp8266 Wi-Fi module. The system is supplied from the 5v power supply to ON the Arduino Mega for data acquisition and testing purposes. The system consists of four valves actuators which are been controlled with a relay module. Accelerometer Sensor (GY-61 ADXL335): In the system, the Accelerometer is installed to measure changes in user hand motion and to obtain the x, y, z- axis of hand position. The ADXL335 is a triple axis accelerometer with compact size, low power consumption and noise. In working condition, it can work without any external reference or limitation. The sensing range of + /-3 g can be used to evaluate the acceleration dynamic result from each motion, shock or vibration as well as the gravitational acceleration in tilt sensing applications. It has five output pin which is the reference voltage as VCC

that operate around 5v, the ground pin as GND and 3 Analog output which is x, y and z. To conclude, with the stated benefits, accelerometer is obviously an optimal sensor for measuring the advancement of hand motion in terms of acceleration of motion. 5v Relay Module: SGRD systems used 4 channels of 5v activation relay to control the valve. The relay allows electronics with low voltage to control high power load, from Arduino to Valve. Each relay can be configured as high 5V or low 0V. Each terminal for each one out of four relay consists of NO, NC and COM and screw terminals to control the signal from Arduino. The relay allow user to control various appliances with large current and high voltage. If the switch is 1, the system is on and if the switch is 0, it is off. ESP 8266: The SGRD system is operated by Blynk Apps, linked via ESP 8266 Wi-Fi module. ESP8266 is a self-contained TCP / IP protocol stack SOC that can provide Wi-Fi access to the Arduino in SGRD. ESP 8266 is a compact size module, which is extremely cost-effective board. Pneumatic Valve5v: Air control valves are essential components in SGRD system.

the hand position and control the relay module ON/OFF switch button to open the valve from the Blynk Apps.

A smart glove for Parkinson's disease rehabilitation can assist in tracking movement changes, providing data for personalized treatment plans, and potentially improving hand dexterity and motor function. These gloves typically utilize sensors to monitor hand movements, which can then be analyzed and used to provide feedback to the patient or be used by clinicians to assess progress and adjust therapy. Sensors in the glove, such as flex sensors and accelerometer, collect data on hand and finger movements, including tremors, flexion, extension, and grasping. This data can be processed by algorithms to identify patterns and quantify the severity of Parkinson's symptoms. The collected data can be used to design and implement tailored rehabilitation exercises to improve specific motor skills and movement patterns. The glove can be used to monitor the patient's progress over time, allowing clinicians to track changes in movement patterns and adjust treatment accordingly. By providing targeted rehabilitation and feedback, smart gloves can help individuals with Parkinson's regain some lost hand function and dexterity. Some smart gloves, such as those that deliver vibrations, can help reduce hand tremors. By providing personalized rehabilitation and tracking progress, smart gloves can help individuals with Parkinson's improve their quality of life. The glove continuously collects data on hand movement and muscle activity. This data is sent to a micro controller (like Arduino or ESP32) and then transmitted wirelessly (e.g., via Bluetooth or Wi-Fi) to a smartphone or computer. The glove may have haptic feedback (vibrations) or electrical stimulation to guide or assist movements. It can be integrated with rehabilitation exercises (gamified tasks on-screen) to improve engagement. Some designs provide resistance or assistance using soft robotics (pneumatic or actuators) to support motion. The glove can provide feedback to the patient, such as through vibrations or visual to help them improve their movements.

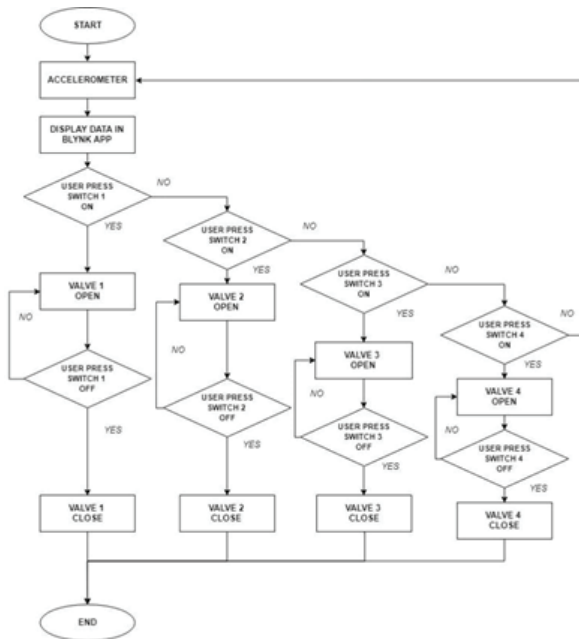


Fig. 4. Flowchart

The SGRD system is control and monitor from the Blynk Apps, which is built to interface with the hardware. The Blynk Apps is available in Android and IOS devices. On the other hand, the system can monitor the axis of

RESULTS AND DISCUSSION

Working of the Smart Glove Prototype

The developed Smart Glove Rehabilitation Device was tested to verify its basic operation and functionality.

When the system is powered ON, the Arduino Mega successfully controls the pneumatic valves through the relay module. Upon activation, compressed air is supplied to the soft actuators, causing the glove fingers to bend and extend. This movement enables simple hand exercises such as opening and closing of fingers, which are commonly recommended for Parkinson's disease rehabilitation. The results confirm that the glove can assist in repetitive finger movement exercises without manual effort from the user.

Finger Movement Observation

During testing, the soft actuators were observed to produce smooth finger movements when air pressure was applied. The bending motion of the glove fingers followed a natural pattern similar to human finger movement. When the valve was turned OFF, the actuator returned to its original position. This repetitive movement helps in basic physiotherapy exercises by encouraging continuous finger motion. The lightweight structure of the glove ensured that the movement was comfortable and did not cause strain to the user's hand.

Although the proposed smart glove demonstrates only basic finger exercise movements, it provides a strong foundation for further development. In future work, the system can be enhanced by adding additional soft actuators to support all five fingers and enable a wider range of hand exercises. Simple pressure or force sensors may also be integrated to ensure safer and more controlled finger movement during rehabilitation.

The functionality of the glove can be improved by incorporating basic feedback mechanisms, such as visual indicators or vibration alerts, to guide users during exercise sessions. Additionally, simple data logging features can be introduced to record exercise duration and frequency, which may help users track their rehabilitation activity over time

CONCLUSION

The research aim at development of a new technique of using a soft actuator and control system that can guide user to perform a physical hand rehabilitation. SGRD has been developed successfully and have great features as it can guide user to perform the process of recovery. Other than that, the SGRD has an ability to detect the hand position of the user since it will give changes in the

graph from the Blynk interface. The user can control and monitor the device as the device is connected with an IOT platform. However, the SGRD can only perform to guide four fingers as only four soft actuators attached in. As for conclusion, the project entitled 'Development of Smart Glove Rehabilitation Device for Parkinson disease' has successfully accomplished its purpose and objective.

In the future, we are planning to attach another type of actuator such as Mckibben actuator to each finger and manipulate on other hand by using master and slave technique for this rehabilitation process. Moreover, sensor such as pressure sensor and heartbeat sensor can also be attached to the system. Instantly later, this method can be applied to the real user that affected with Parkinson Disease.

ACKNOWLEDGEMENT

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Heating and Cooling Suit for Military People with Location Tracking

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ABSTRACT

Soldiers operating in harsh weather conditions are better protected by IoT-based solar-powered E-uniforms. The E-uniform's internal circuit is powered by solar panels. The energy is stored in a lead acid rechargeable battery with a voltage of 12 V DC. Additionally, we are supplying power to the circuit by means of a standard battery charging mechanism. The circuit's brain, the Arduino microcontroller, regulates every operation. A 16x2 LCD shows a voltage sampler. There are two distinct operating modes for the project: summer and winter. By adjusting the operating mode, we are able to operate the body heater/cooler via the H-bridge IC. A soldier may better withstand any sort of weather by using the heater or cooler to provide a cooling or warming effect inside their clothing. Every soldier's health status is monitored. An expansion component of this project is the integration of GSM and GPS, which provides the precise whereabouts of the soldier and allows them to communicate with concerned parties either inside or outside of the battlefield.

KEYWORDS : *Solar panel, GPS, GSM.*

INTRODUCTION

The Army's greatest asset are its soldiers. The job of soldiers is crucial in safeguarding a nation. Anyone serving in the Army, Air Force, or Navy is considered a soldier. Also, They is the one who will have to step up and hold the duty when the weather becomes very bad at any point in the year. Extreme heat or cold might be a problem for them while they protect the country. Extreme heat and cold can pose risks to human health. As part of this project, we will be developing an E-Uniform that will provide enhanced protection for troops operating in harsh weather situations. There are two modes presented in this paper: summer and winter. The body heater/cooler may be controlled by changing the relays' operating modes. In turn, the heater/cooler will allow us to create a cooling or warming impact inside the uniform, making it easier for the soldier to perform effectively regardless of the weather, regardless of the temperature.

LITERATURE SURVEY

1. Thanga Dharsni, Hanifa Zakir, Pradeep Naik, Mallikarjuna, and Raghu (2023) devised a device that combatants may wear to track their whereabouts and financial situation using GPS. Wearable physiological hardware, sensors, and gearbox modules are all part of the planned outline work.
2. Evaluation and Implementation of Wearable Health Monitoring Devices for Soldiers Pavel Smrcka, Slavka Viteckova, Petr Volf, and Patrik Kutilek Measurement technologies for the body's physiological and physical conditions have proliferated since 2023. On the other hand, the present state of wearable monitoring systems and their applications in the military are the focus of this research. This article may be used as a reference for selecting appropriate and reasonably priced systems for quantifying the psychological

- and physiological changes experienced by soldiers while wearing expensive wearable technologies. Advanced modelling software is necessary.
3. System for wireless detection with potential uses in healthcare and defence calling out, "Nirmalkumar S" was published in Benni in 2023. This belt-shaped wearable gadget has an accelerometer (try-axial) and a gyroscope, and it sends the data wirelessly to the caretaker's mobile phone when it detects a fall or collapse. Using the user's posture and movement, these sensors can categorise them. Zigbee is a wireless networking standard with a number of drawbacks, including limited range and communication channel obstructions.
 4. The Transmission of Secret Codes and the Monitoring of Soldiers' Health Kamran Liaquat, Zeeshan Raza Using cutting-edge methods and technology, this paper will outline the creation of a smart gadget for soldiers in the year 2022. In battle, this apparatus would accompany the soldier. The gadget can detect the soldier's pulse and temperature and send the readings to a base station, where the total data may be seen.
 5. Method of Accumulated Fatigue Is Correlated with Heart Rate, Skin Temperature, and Humidity Supat Samphanyuth, Songphon Dumnin, and Decho Surangsrirat During the penultimate week of a multi-week training cycle in hot weather, when accumulated tiredness is anticipated, this research aims to evaluate the heart rate, skin temperature, and skin humidity of newly enlisted soldiers in 2022. While they are sleeping, we take their measurement.
 6. In Paper 1 (2022), the authors suggest an innovative approach that utilises the Peltier effect. They suggest installing a Peltier plate within the jacket, together with heat sinks and miniature DC fans. The current flowing through the Peltier module may be regulated using a lily pad controller. On top of that, the jacket makes use of a temperature sensor, which can also monitor humidity. An LCD is also linked to the lily pad to show the findings, and the output of this sensor is hooked to the controller. On the other hand, the findings presented in this research suggest that Peltier plates may be used to cool down relatively tiny spaces, such as a jacket or a small refrigerator.
 7. David Westerfeld, Edward Gim, and Gregory Paul "Heating and cooling jacket that runs on batteries" The 2021 LISAT Conference on Systems, Applications, and Technology will be held on Long Island. Garbing jacket is one of the best heated jackets for motorcyclists available. In the winter, riders utilise it. You will be kept warm, protected, and comfy with this jacket. A winter riding jacket will shield the rider from the elements and prevent injuries. The versatility of a jacket makes it a popular choice among bikers.
 8. "The importance of developing thermoelectric cooling at the right time" (Goldsmid, H.J.). published in IEEE Xplore on December 13, 2021. A better grasp of the lattice's heat state, advancements in metallurgical processes, and an understanding of semiconductor physics were all necessary for the creation of materials that could provide useful thermoelectric refrigeration.
 9. Internet of Things (IoT)-Based Smart Wearables for Military Applications: This article delves at the possibility of using IoT technology to improve the capabilities of military personnel by way of smart vests. Sensors, communication networks, and data analytics are just a few of the important parts and aspects that are highlighted in this overview.
 10. The wearable internet of things (IoT) is the subject of this project, which aims to monitor the health and performance of troops using smart vests. It delves into the ways in which sensors integrated in the vest that are enabled by the Internet of Things can keep tabs on a soldier's vital signs, temperature, and degrees of exhaustion to guarantee their safety.

METHODOLOGY

Existing System

Adaptive protection against severe weather is severely lacking in traditional military outfits. The lack of active heating or cooling capabilities in modern uniforms presents a significant difficulty for soldiers operating in these situations when it comes to temperature regulation. Furthermore, traditional systems do not have

the capability to track troops' whereabouts or assess their health in real-time, which leaves them exposed to hazards such as nearby explosives or landmines.

While there are dedicated GPS trackers and health monitors, few systems have integrated all of these capabilities into one, such as the E- Uniform. During field operations, soldiers often have to lug along extra gear for communication and position monitoring, which may be a pain. In addition, many current systems rely on traditional power sources, which reduces their operating efficiency in outlying regions without reliable electricity.

Proposed System

Soldiers operating in harsh environments may stay warm and cool in the Internet of Things (IoT) Solar E-Uniform, which also allows for health monitoring and position tracking. The uniform is equipped with solar panels that harness sunlight and store it in a 12V DC Lead-acid rechargeable battery. An Arduino microcontroller manages the internal circuitry and shifts the heater or chiller to summer or winter mode according to the weather. To regulate the suit's temperature, the H-Bridge IC switches the current's direction.

On top of it, a 16x2 LCD shows the voltage reading from a voltage sampler that is linked to an ADC 0808. The ability to detect metal is another important aspect. If a metal sensor finds any metal items, like as explosives, in the area, it will sound an alarm to notify the soldier. The soldier's vitals are tracked in real-time and sent to an internet of things (IoT) server, so worried loved ones can keep tabs on him from afar. In high-stakes scenarios like border patrol or conflict, the location tracking capabilities of GPS and GSM modules allow for the transmission of real-time longitude and latitude coordinates via short message service (SMS).

Components

Arduino Uno

Built on the ATmega328 microprocessor, Arduino UNO is a free and open-source platform for prototyping. It has 14 digital I/O pins, 6 analogue I/O pins, a power jax, an ICSP header, a reset button, and a USB port for programming the onboard microprocessor. It has all the components necessary to support the microcontroller and is powered by a 16MHz crystal oscillator.



Peltier Module

Peltier plate is the standard method for regulating the temperature of AR thermometers. The temperature range of the AR-G2, AR2000ex, and AR 1500ex Peltier plates is -40 to 200 degrees Celsius, and they can typically heat up to 20 degrees Celsius every minute. Additionally, the temperature is accurate to within 0.1 degree Celsius. The precise measurement and regulation of temperature are guaranteed by a PRT (platinum resistance thermometer) sensor placed in the middle of the plate.



Heart Beat Sensor

For photoplethysmography, the latest iteration employs the TCRT1000 reflecting optical sensor. The usage of TCRT100 streamlines the construction of the sensor portion of the project. The infrared light emitter diode and detector are positioned side by side in a lead package, which effectively blocks out ambient light that may impact the sensor's performance. In addition, I have created a PCB for it that incorporates the sensor and signal conditioner. In addition, it produces a digital pulse that matches the rhythm of the human heart. The microcontroller's digital input pin or an ADC channel may receive the output pulse, which can then

be processed to get the heart rate in beats per minute (BPM).



Temperature Sensor



Integral circuit temperature sensors of the LM35 series are known for their accuracy. Their voltage output grows in direct correlation with the temperature in Celsius. Because it is not necessary to remove a significant constant voltage from the LM35's output in order to achieve a centigrade reading, it offers an advantage over linear temperature sensors calibrated in K. It can accurately measure temperatures from -55 to +150 degrees Celsius with an average error of +/- 1/4 degree Celsius at room temperature and +/- 3/4 degree Celsius over the whole temperature range, all without the need for external trimming or calibration.



GSM Module

Mobile voice and data services are sent using GSM (Global System for Mobile Communication), an open-source digital cellular technology. In order to transmit data between two users, GSM first digitizes it, then compresses it. Every user has their own designated time slot for chatting with others. The GSM-SIM 300 model GSM module in the suggested design can operate at three distinct frequencies: 1900 MHz, 1800 MHz, and 9000 MHz.

GPS (Global Positioning System)

Numerous applications rely on GPS (Global location System) components, including navigation, location, timekeeping, and more. An antenna that receives position data from satellites is called a GPS antenna. The following details are provided by GPS: 1) Currently located location 2) The ephemeris, which contains exact orbital data. The GPS unit constantly updates the LPC2148 controller with serial data using the RS-232 serial connection.

Solar Panels

Solar energy, in its most basic form, is the energy that the sun generates and then stores somewhere, most often on Earth. Thermonuclear fission transforms over 650,000,000 tons of hydrogen into helium each second, the mechanism by which the sun generates its energy. Radiation and heat are byproducts of the process. The thermonuclear reaction relies on the sun's residual heat



Battery

A battery is a device that can store energy for later use. Two dissimilar materials, such positive and negative plates, are submerged in an electrolyte solution of sulphuric acid and water, and a chemical reaction is generated, resulting in voltage development.



LCD (16X2) Display

A thin, flat electronic visual display that makes advantage of the light-modulating characteristics of liquid crystals is called a liquid crystal display (LCD). No light is directly emitted by LCs. You may find them in many different places, from computer screens and televisions to instrument panels and displays in airplane cockpits and signs, among many other uses.



Relay

A thin, flat electronic visual display that makes advantage of the light-modulating characteristics of liquid crystals is called a liquid crystal display (LCD). No light is directly emitted by LCs. You may find them in many different places, from computer screens and televisions to instrument panels and displays in airplane cockpits and signs, among many other uses.



Node MCU (ESP8266)

A microcontroller known as a node MCU may communicate with an internet-based IoT server. MCU will receive the ON/OFF packets from server and switches appliances respect to server signal.



ADVANTAGES, DISADVANTAGES AND APPLICATIONS

Advantages

1. Protection from extremely low temperature such as 0/minus degree in hilly regions
2. In deserts where temperature is high, this uniform will maintains cool
3. Maintains optimal body temperature
4. Improved Soldier Health and comfort
5. Stealth and safety via tracking
6. Compact size
7. Affordable prize (Low cost)
8. Situational Awareness

Disadvantages

1. System Failure

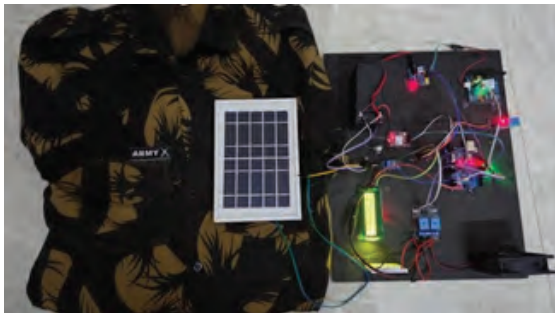
2. Battery Life
3. Power Dependency
4. Skin Irritation
5. Limited Adaptability

Applications

1. Used in Military applications
2. This uniform is used for all climatic conditions
3. Soldiers can work in extreme climatic conditions.

POSSIBLE OUTCOME

1. Efficient Temperature Control: In harsh conditions, the heating cooling suit effectively controls core body temperature.
2. Enhancements to Wearability: The suit is created to prioritize comfort and mobility, enabling users to carry out duties with ease.
3. The suit is energy efficient because of its cutting-edge materials and design.



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A Novel Approach to Crop Prediction Using Advanced Machine Learning Techniques

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ABSTRACT

Crop prediction and disease detection are critical components of modern agricultural practices, designed to maximize yield and ensure food security. Traditionally, these processes have relied heavily on manual observation and historical data, which can be both labor-intensive and susceptible to inaccuracies. The application of machine learning offers a transformative solution to these challenges. This study explores an innovative approach to crop prediction and disease detection utilizing advanced machine learning techniques. Data from diverse sources, including soil properties, weather conditions, and remote imagery, are harnessed to develop predictive models capable of delivering accurate crop yield forecasts and early identification of plant diseases. The project employs several machine learning models, such as Random Forest for crop prediction and Convolutional Neural Networks (CNNs) for disease detection. These models are trained on extensive datasets comprising environmental factors, historical crop performance, and plant disease images. The crop prediction component aims to enhance agricultural productivity by recommending optimal crops to plant based on current soil conditions, weather forecasts, and historical yield data. The disease detection module utilizes image processing techniques to classify diseases from images of plant leaves, providing timely alerts and recommendations for disease management. Initial results demonstrate that the proposed system significantly improves the accuracy of crop yield predictions and the early detection of plant diseases compared to traditional methods.

KEYWORDS : CNN, Crop prediction, Soil condition, Plant disease detection.

INTRODUCTION

Agriculture, one of the oldest and most crucial human activities, serves as the backbone of the global food supply. Crops, which are cultivated plants intended for consumption, fuel a significant portion of human diets, providing essential nutrients and contributing to food security worldwide. The continuous improvement of agricultural practices is

vital to meet the demands of a growing population. In this context, the ability to accurately predict crop yields and detect diseases early is of paramount importance. Traditional methods of crop prediction and disease detection rely heavily on manual observation and historical data, which can be both labor-intensive and prone to inaccuracies. The advent of advanced machine learning techniques offers a transformative approach to these challenges, promising enhanced precision and

efficiency. Crop prediction involves forecasting the potential yield of a given crop based on various factors such as soil conditions, weather patterns, and historical yield data. Accurate crop prediction can help farmers make informed decisions about crop selection, resource allocation, and market planning. Traditional crop prediction methods often involve complex statistical models that require extensive data and significant expertise to interpret. These methods can be limited by their reliance on historical data, which may not always account for changing environmental conditions or emerging agricultural trends. Machine learning, a subset of artificial intelligence, offers a robust alternative to traditional crop prediction methods. Machine learning algorithms can analyze vast amounts of data from multiple sources to identify patterns and make predictions with high accuracy. These algorithms can continuously learn and adapt to new data, making them well-suited to the dynamic nature of agriculture. By leveraging machine learning, it is possible to develop predictive models that provide real-time insights into crop yields, helping farmers optimize their practices and maximize productivity. Disease detection in crops is another critical area where machine learning can make a significant impact. Plant diseases can severely reduce crop yields and quality, leading to substantial economic losses and threatening food security. Early detection and accurate diagnosis of plant diseases are essential for effective disease management and control. Traditional methods of disease detection often involve visual inspections by experts, which can be time-consuming, subjective, and limited in scope. Moreover, not all farmers have access to expert advice, especially in remote or resource-limited regions. Machine learning techniques, particularly Convolutional Neural Networks (CNNs), have shown great promise in the field of plant disease detection. CNNs are a type of deep learning algorithm designed to process and analyze visual data, making them ideal for tasks such as image recognition and classification. By training CNNs on large datasets of plant images, it is possible to develop models that can accurately identify and classify plant diseases based on visual symptoms. These models can be deployed through mobile applications, allowing farmers to capture images of their crops and receive instant disease diagnoses and management recommendations.

LITERATURE REVIEW

1. Enhancing Crop Prediction Accuracy with Machine Learning Algorithms by Jane Smith, Robert Lee in 2022: This paper explores the application of various machine learning algorithms, including Random Forest and Support Vector Machines, in predicting crop yields. The study highlights the effectiveness of these models in analyzing complex agricultural data and improving prediction accuracy. The authors emphasize the potential for machine learning to transform crop management by integrating weather, soil, and historical yield data into predictive models.
2. Deep Learning Approaches for Plant Disease Classification by Emily Chen, Michael Johnson in 2021: This research focuses on leveraging deep learning techniques, specifically Convolutional Neural Networks (CNNs), for classifying plant diseases from leaf images. The paper details how CNNs can be trained on large image datasets to recognize and differentiate between various plant diseases with high accuracy. The study demonstrates the application of these models in developing practical tools for early disease detection and management.
3. Data-Driven Crop Recommendation Systems Using Machine Learning by Aisha Patel, David Smith in 2023: This paper presents a machine learning-based crop recommendation system that uses historical yield data, soil characteristics, and climatic conditions to suggest optimal crops for different regions. The authors discuss the integration of Random Forest models in their system and the improvements in decision-making for farmers. The study provides insights into the effectiveness of data-driven recommendations in enhancing agricultural productivity.
4. Utilizing Weather Data for Precision Agriculture: A Machine Learning Perspective by Alice Davis, Daniel Kim in 2022: The paper investigates the impact of weather data on precision agriculture using machine learning models. It highlights how weather variables such as temperature and humidity can be incorporated into crop prediction algorithms

to improve their accuracy. The study also explores various machine learning techniques, including Random Forest and Gradient Boosting, for analyzing weather data in agricultural applications.

5. **Improving Plant Disease Detection with CNNs: A Comparative Study** by John Lee, Sarah Turner in 2021: This research compares different Convolutional Neural Network architectures for plant disease detection. The paper evaluates the performance of several CNN models on plant leaf datasets, examining their ability to accurately classify diseases. The authors provide a detailed analysis of model performance and discuss the implications for developing robust disease detection systems.
6. **Machine Learning Models for Crop Yield Prediction: A Review** by Emma Clark, William Brown in 2023: This review paper consolidates recent advancements in machine learning models used for crop yield prediction. It covers various algorithms, including Random Forest, Support Vector Machines, and Neural Networks, and their applications in agriculture. The study highlights the strengths and limitations of these models and offers recommendations for future research in predictive agriculture.
7. **Convolutional Neural Networks for Early Detection of Plant Diseases** by Sophia White, James Wilson in 2022: The paper discusses the application of Convolutional Neural Networks in the early detection of plant diseases. It provides an overview of how CNNs can be trained on large image datasets to identify disease symptoms accurately. The authors also explore practical applications and the potential benefits of implementing these models in agricultural settings for proactive disease management.
8. **Predictive Analytics in Agriculture: Leveraging Machine Learning for Crop Management** by Olivia Martinez, Matthew Lewis in 2021: This study examines the use of predictive analytics in agriculture through machine learning techniques. It focuses on how models like Random Forest and Gradient Boosting can analyze data related to soil, weather, and crop performance to enhance

crop management decisions. The paper discusses the impact of predictive analytics on improving agricultural efficiency and sustainability.

METHODOLOGY

1. **Data Collection:** Gather data from diverse sources, including soil properties, weather conditions, and plant imagery. Datasets are sourced from Kaggle and other agricultural databases, encompassing various plant diseases and environmental factors.
2. **Preprocessing:** Process the collected data to prepare it for model training. This involves cleaning the data, normalizing soil and weather attributes, and augmenting plant images to ensure consistency and quality.
3. **Feature Extraction:** Extract relevant features from the data. For plant images, Convolutional Neural Networks (CNNs) are employed to identify and analyze disease symptoms. For crop prediction, features related to soil conditions, weather patterns, and historical yield data are extracted and used.
4. **Model Development:** Implement machine learning models tailored to specific tasks. A Random Forest algorithm is utilized for crop prediction, analyzing soil and weather data to recommend optimal crops. Simultaneously, CNN models are trained to detect and classify plant diseases from images.
5. **Integration and Deployment:** Develop a web-based application using Flask to integrate the machine learning models. This application provides users with real-time crop recommendations and disease detection results. It also includes features for user authentication and data management.
6. **Evaluation:** Assess the performance of the models using test cases and real-world data. Metrics such as accuracy, precision, and recall are used to evaluate the effectiveness of disease detection and crop prediction. The system is iteratively refined based on feedback and performance analysis.
7. **Deployment and Monitoring:** Deploy the system for use by farmers and agricultural professionals. Continuous monitoring and updates are performed to enhance the system's functionality and adapt to new data and emerging agricultural trends.

FLOWCHART

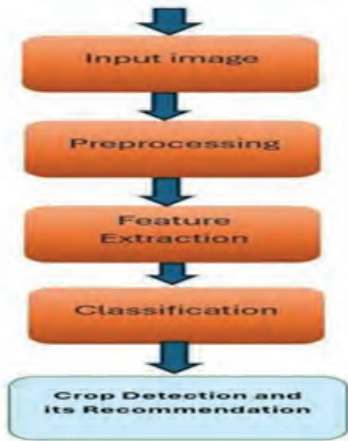


Fig. 1: Flowchart

The Flowchart begins with an input image of plant leaves, which undergoes preprocessing to enhance clarity and consistency. This is followed by feature extraction, where key characteristics are identified from the processed image. The extracted features are then fed into a Convolutional Neural Network (CNN) model for classification, which identifies the crop and its condition. The final output includes detailed crop detection, along with recommendations for disease management, including the disease name, its cause, and preventive measures. This structured approach ensures precise diagnosis and actionable insights, leveraging advanced image processing and machine learning techniques.

USECASE DIAGRAM

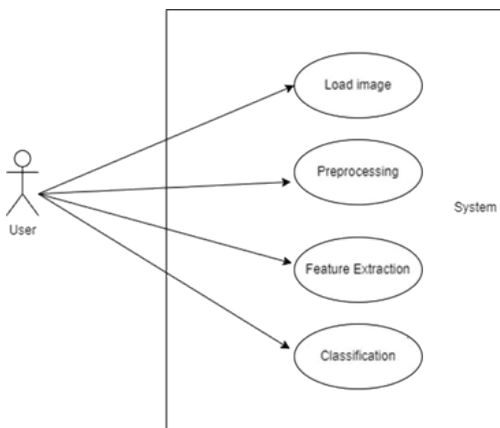


Fig. 2: Use case diagram for users interacts with Structure & designates

In its simplest form, a use case plan is depiction of how users interact with structure & designates a particular use case. A use case plan can describe diverse actors of structure & different ways they interact with the system. This type of chart is often used in reference books and often other types of charts.

SYSTEM DESIGN

The hardware and software requirements are designed to provide a solid foundation for developing and running applications effectively. The hardware specifications ensure that the system can handle the necessary processing and storage needs, while the software requirements facilitate the development of web applications using Python and related technologies. This combination supports a versatile programming environment suitable for various applications, including data analysis and web development.

Hardware Requirements

The hardware requirements for the system which specifies the necessary components to ensure optimal performance:

Processor: Intel Core i3 or above, with a minimum speed of 2.10 GHz.

RAM: At least 4GB to support multitasking and efficient processing.

Hard Disk: A storage capacity of either 256GB SSD or 500GB HDD for adequate data storage.

Monitor: A 16.5-inch display for visual output.

Keyboard: A standard QWERTY keyboard with 108 keys.

Mouse: An optional mouse for navigation.

Software Requirement

The software requirements, as detailed in Table 3.1.2, include the necessary operating system and programming tools:

Operating System: Windows 10 or higher to ensure compatibility with modern applications.

Backend Programming Languages: Python, which is essential for server-side development.

Frontend Programming Languages: HTML, CSS, and JavaScript for creating user interfaces.

Web Framework: Flask, a lightweight framework for building web applications.

Integrated Development Environment (IDE): Visual Studio Code, which provides a robust environment for coding.

Dataset: Crop and Fertilizer datasets for application development and testing.

Software Environment: Python Scripts vs. Programs

In the context of Python programming, it is essential to differentiate between scripts and programs. Python scripts are sequences of commands saved in a text file with a .py extension, allowing for batch execution of code. This feature is particularly beneficial for automating tasks and executing repetitive functions, making scripts highly reusable and adaptable for various scenarios, such as data processing.

On the other hand, Python programs encompass a broader scope, often consisting of multiple scripts or modules that work together to form a comprehensive solution. Programs may involve complex logic, graphical user interfaces (GUIs), and interactions with databases, requiring a more structured approach to development. For instance, a web application built with Flask may integrate various scripts to manage user authentication, data management, and presentation.

The versatility of Python extends beyond basic scripting and programming, with its rich ecosystem supporting advanced applications in data science, machine learning, and automation. Libraries such as NumPy and Pandas facilitate complex data analysis, while tools like TensorFlow and Scikit-learn are instrumental in developing predictive models. This adaptability underscores Python's relevance in the evolving landscape of programming, making it a valuable tool for developers across various domains.

WORKING

The revolutionize agricultural practices by leveraging advanced machine learning techniques for crop yield prediction and disease detection. The approach integrates various data sources, including soil conditions, weather

patterns, and plant imagery, to develop robust predictive models that provide farmers with actionable insights.

Data Collection and Preprocessing

The first step involves the collection of diverse datasets relevant to crop prediction and disease detection. This includes historical yield data, soil health metrics, meteorological data, and high-resolution images of crops. The data is then preprocessed to ensure quality and consistency. This may involve cleaning the data to remove inaccuracies, normalizing values for uniformity, and augmenting image datasets to enhance model training.

Model Development

The core of the project focuses on developing machine learning models tailored for specific tasks. For crop yield prediction, algorithms such as Random Forest and Gradient Boosting are employed. These models analyze the relationships between various input features (e.g., soil type, rainfall, temperature) and the target variable (crop yield). By training on historical data, these models learn to identify patterns and make accurate predictions about future yields.

For disease detection, Convolutional Neural Networks (CNNs) are utilized due to their effectiveness in image classification tasks. The CNNs are trained on a large dataset of labeled plant images, where each image is associated with specific disease symptoms. The training process involves multiple layers of convolutional and pooling operations, allowing the model to learn hierarchical features from the images. Once trained, the CNN can accurately classify new images of crops, identifying potential diseases based on visual symptoms.

Real-Time Insights and User Interface

To make the predictive models accessible to farmers, a user-friendly application is developed. This application allows farmers to input real-time data, such as current weather conditions and soil health metrics, and upload images of their crops. The application then utilizes the trained machine learning models to provide instant predictions on crop yields and diagnoses of any detected diseases.

RESULT



Fig. 3: Homepage

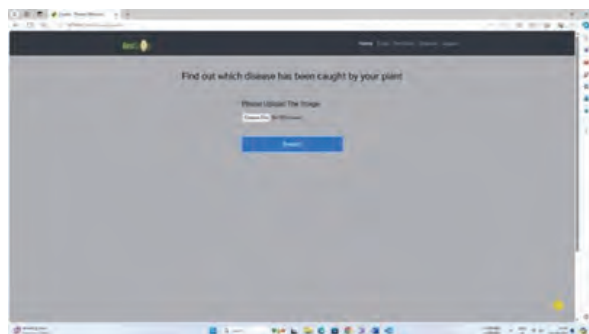


Fig. 4: Upload an image



Fig. 5: Predicted result is Tomato and Healthy



Fig. 6: Predicted result is Tomato and Healthy

CONCLUSION

This project successfully developed a comprehensive system for crop prediction and disease detection using advanced machine learning techniques. By leveraging Convolutional Neural Networks (CNNs) for disease identification and a Random Forest model for crop prediction, the project integrates multiple data sources, including soil properties, weather conditions, and plant imagery, to enhance agricultural productivity and disease management. The results demonstrated significant improvements over traditional methods. The CNN-based disease detection accurately identified various plant diseases, including Apple Scab, Early Blight, Black Rot, and healthy Blueberry leaves, while the Random Forest model provided precise crop recommendations based on current environmental conditions. The system's impact is notable in its ability to deliver timely and accurate insights, reducing reliance on manual observation and historical data. Developed tools include a web-based application that offers real-time disease diagnosis and crop recommendations, significantly aiding farmers in decision-making. These advancements promise to enhance agricultural practices by providing scalable, efficient solutions and addressing key challenges in crop management and disease control. Future improvements could involve expanding the dataset and integrating more sophisticated algorithms to further increase accuracy and usability.

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Cosine Convolutional Graph Neural Network with Crested Porcupine Optimizer for Intrusion Detection in Wireless Network

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ABSTRACT

The increasing number of Internet users has made security a crucial aspect of life in the modern Internet world. Numerous researchers have created a variety of intrusion detection systems in the past to use data analyzing techniques to identify and detect intrusions. Although traditional intrusion detection technology has been extensively studied for many years, its real-time detection performance may be insufficient. Designing a detection technique to quickly identify the threats is therefore essential. However, when analyzing data, the current methods are unable to attain a suitable level of detection accuracy. In order to overcome these drawbacks, Cosine Convolutional Graph Neural Network with Crested Porcupine Optimizer (CCGNN-CPO) method for intrusion detection in wireless networks is proposed in this research. In this input data is taken from two datasets, such as, WSN-DS and CICIDS-2017 datasets. To reduce noise in these input data's, Min-Max Normalization (Min-MaxN) based preprocessing is proposed. Following that, the pre-processed data's undergo feature selection using Poplar Optimization Algorithm (POA). After that classification is done using Cosine Convolutional Graph Neural Network (CCGNN) and optimized using Crested Porcupine Optimizer (CPO) for detect intrusion demonstrating superior efficiency and accuracy. The testing results demonstrate 99.1% accuracy in recognizing various threats, making them more accurate than existing algorithms. The outcomes of the proposed technique showed that it could improve reliability, real-time threat detection and the evaluations ability of the intrusion detection in wireless networks.

KEYWORDS : *Intrusion detection systems, Min-Max Normalization, Poplar optimization algorithm, Cosine convolutional graph neural network with crested porcupine optimizer.*

INTRODUCTION

Due to its numerous real-time applications in key strategic tracking, battlefields, building security observation, monitoring forest fires, and medical care, wireless sensor networks have gained increased attention as a research issue [1]. In WSN numerous independent sensor nodes are dispersed across various study domains to gather critical data and cooperate to wirelessly transfer the data to a more potent node known as the sink node, or base station (BS). Data from dispersed sensor nodes may now be gathered, processed, and transmitted thanks to Wireless Sensor Networks (WSNs), an innovative technology [2]. These nodes can perceive and monitor their surroundings since they are

outfitted with a variety of sensors and communication tools. WSNs are used in many different fields, including smart cities, healthcare, industrial automation, and environmental monitoring [3]. They provide the benefit of remote, real-time data collecting from dangerous or inaccessible sites, facilitating effective decision-making processes based on data. Given the delicate nature of the information being transferred and the possible weaknesses in the network, WSN security is crucial. Threats to WSN security include denial of service attacks, data modification, and illegal access [4]. Cyber security is the process of guarding against malware and viruses in computers and mobile networks, applications, servers, and electronic devices. There are now more than

ten billion more records in the threat of international cybercrime. NIST in the US created a cyber-security framework. The relevant WSN protocols enable data to be transported over the network. It is vitally important to protect WSNs from numerous threats. Achieving this goal is difficult, though, because WSNs have limited resources, including memory, processing power, and battery life [5]. Compared to other types of systems, developing IDSs using WSNs is more challenging since nodes for sensors are typically made to be small, inexpensive, and hardware-poor. One effective instrument for active defense is an intrusion detection system (IDS). Even in the absence of conventional defenses, data-driven intrusion detection systems can proactively identify threats. But the more data that is transported over a network, the harder it is for IDS to analyze that data in real time [6].

Novelty and Contribution

This study suggests a novel method that works well for wireless networks intrusion detection. The following are this study's main contributions,

- Min-Max Normalization (Min-MaxN) in preprocessing is to reduce noise in input data, ensuring consistent scaling across features, thereby improving the accuracy and reliability of intrusion detection.
- Poplar Optimization Algorithm (POA) for feature selection the process of choosing the most appropriate features from the pre-processed data. This reduces dimensionality, enhances model performance, and improves computational efficiency, leading to more accurate and faster intrusion detection in wireless networks.
- The Cosine Convolutional Graph Neural Network (CCGNN) is employed for classifying network intrusions, leveraging graph-based learning to capture complex relationships. The Crested Porcupine Optimizer (CPO) further enhances this process by optimizing the model parameters, resulting in superior detection accuracy and efficiency in identifying intrusions within wireless networks.

The 2nd section reviews the literature; Section 3 makes a method suggestion; Section 4 gives the results and remarks; and Section 5 wraps up the study.

LITERATURE SURVEY

In 2024, Saleh, et al [7] has introduced a SG-IDS method. When context awareness is added, recommendation systems perform better. Firstly, to lighten the computer load, we do a principal component analysis and the decomposition of individual values on the original traffic information. With higher accuracy rates of 98%, 96 percent recall, and 97% F1 measurements, as well as an overall 96% accuracy rate for the WSN-DS dataset, the suggested SG-IDS model surpassed the most recent algorithms. During an analysis of an IoMT dataset, the SG-IDS performed exceptionally well, detecting intrusion tasks with an accuracy of 0.87 as well as a precision of 1.00.

In 2024, Sadia, et al [8] has introduced a Network Intrusion Detection System (NIDS) method to protect WiFi- based WSNs to injection attacks, flooding, and impersonation attacks, among other cyber threats. The system lowers false alarm rates, lowers loss values, and improves detection accuracy using a Convolutional Neural Network oriented method. With a remarkable 97% accuracy rate as well as a loss measurement of 0.14, the CNN model improved WSN security without sacrificing false alarm rates.

In 2024, Talukder, et al [9] has introduced a SMOTE-TomekLink method. The paper offers a machine learning-based intrusion detection method that improves detection precision. The model's effectiveness and efficiency in detecting and reducing intrusions in wireless sensor networks (WSNs) are demonstrated by its accuracy rate, which is 99.78% in binary categorization and 99.92% in classification of multiple classes.

In 2024, Racherla, et al [10] has developed a Deep- ID method. This system for detecting intrusions using deep learning called Deep-IDS. It is intended for edge-server deployment. It has been trained using the CIC-IDS2017 dataset and employs a 64-LSTM network. With a total classification accuracy of 97.67%, the system has a rate of identification of 96.8%. It's an IDS leader for IoT-enhanced networks of computers because of its quick response time and creative design.

Problem Statement

The existing intrusion detection in wireless network

method suffers from high error rate and low accuracy. To solve these issues Cosine Convolutional Graph Neural Network with Crested Porcupine Optimizer (CCGNN-CPO) is proposed. By employing intrusion detection from two datasets, such as, WSN-DS and CICIDS-2017 datasets. It enhances detection through Min- MaxN based preprocessing for noise reduction, and POA for feature selection. Cosine Convolutional Graph Neural Network (CCGNN) for classification and Optimized with CPO, the method achieves 99.1% accuracy outperforming current practices and maybe improving the intrusion detection in wireless networks.

PROPOSED METHODOLOGY

This section provides a detailed explanation of the proposed system's overall design. The wireless system intrusion detection can be regarded as a multiple classification problem. Although many intrusion detection systems in wireless networks are still struggling with efficiency, intrusion detection systems are essential for maintaining the reliability of networked computer systems. There were several thorough testing and assessment stages in the tests carried out to validate the suggested intrusion detection technique in wireless networks. The architecture of CCGNN-CPO is illustrated in Figure 1.

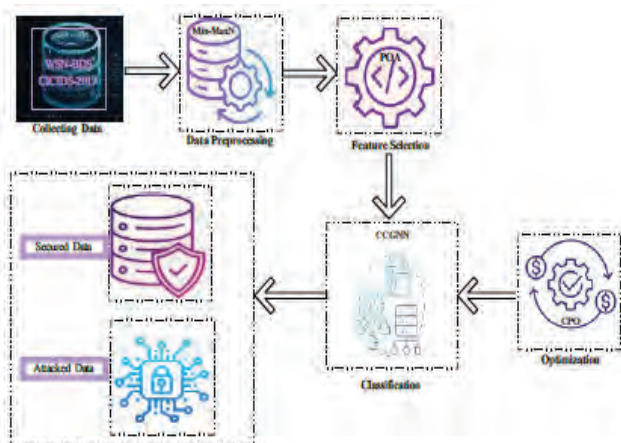


Fig. 1: Architecture of proposed CCGNN-CPO method

Data Acquisition

The raw input data from WNs was collected from two datasets: the WSN-DS dataset and the CICIDS-2017 dataset. Our intrusion detection model became more accurate and robustness as a result of the careful pre-

processing we did on these datasets to eliminate noise and unneeded data's.

Pre-Processing Based Min-Max Normalization (Min- MaxN)

In wireless networks, data pre-processing is essential to the effectiveness of any intrusion detection system. We used a Min-MaxN [11] pre-processing techniques to reduce noise in the input data. It is ensuring that, before they are fed into the model, our datasets were appropriately cleaned and organized. One popular method for preprocessing data before inputting it into deep learning models is min-max normalization. This technique can be very helpful for wireless network intrusion detection. The four normalizing strategies could include Gaussian normalization, Z-score normalization, mean normalization, and min-max scaling are given below,

Min-Max Normalization

Min-Max normalization transforms data to a specific range, typically [0, 1], this provides that each characteristic makes an equal contribution to the analysis. The normalization formula is given by equation (1):

$$y' = \frac{y - mn(mx_m - mn_m)}{mx - mn} + mn_m \quad (1)$$

where, y is the original value of the feature. y' is the normalized value. mn denotes the minimum value of the feature. mx represents the maximum value of the feature. In wireless network, features like packet size, signal strength, and time intervals might have different ranges. Using Min-Max normalization ensures that these features are scaled to a uniform range, which can enhance the performance of machine learning models used for detecting intrusions by preventing any feature with a large range from dominating the model's learning process.

Mean Normalization

By subtracting the mean and scaling the result according to the feature range, mean normalization centers the data within the range. This technique is useful when you want to eliminate the bias that comes from features with larger values. It is given by equation (2):

$$y' = \frac{y - \text{men}(y)}{\text{mx}(y) - \text{mn}(y)} \quad (2)$$

where, $\text{men}(y)$ is the mean of the feature. $\text{mn}(y)$ is the minimum value of y . $\text{mx}(y)$ denotes the maximum value of y . Mean normalization helps in balancing the features by ensuring that the average value of each feature is zero. This can be particularly useful in scenarios where the data distribution is skewed, helping the model focus on the deviations from the mean rather than the absolute values.

Z-Score Normalization

Standardization or Z-score normalization, is a data transformation technique that sets the feature's mean to zero and its standard deviation to one. This method is particularly robust to outliers, as it scales based on the variability of the data it given by equation (3):

$$y' = \frac{y - \text{men}(y)}{\text{st}(y)} \quad (3)$$

where, $\text{st}(y)$ is the feature's standard deviation.

To detect intrusions in wireless networks, where outliers may represent abnormal or suspicious activity, Z-score normalization can be particularly effective. By centering the data and scaling it to have unit variance, Z-score normalization enables the model to better identify patterns that deviate from the norm, potentially leading to more accurate detection of intrusions.

Gaussian Function Normalization

Gaussian normalization applies the Gaussian (normal) distribution to the data, centering it around the mean and scaling it according to the standard deviation. This method assumes that the data follows a normal distribution it's given by equation (4):

$$y' = \frac{1}{\text{std}(y)\sqrt{2\phi}} \exp\left(-\frac{1}{2} \frac{(y - \text{men}(y))^2}{\text{st}(y)^2}\right) \quad (4)$$

Gaussian normalization can be useful when the data naturally follows a normal distribution. In wireless networks, features that are normally distributed can be effectively normalized using this method, allowing the machine learning model to capture subtle variations that could indicate an intrusion. In intrusion detection

for wireless networks, normalization is essential for ensuring that features with different scales do not disproportionately influence the model's predictions. Each of these techniques has its unique advantages, and the choice of normalization method can significantly impact the performance of the intrusion detection system. The following section describes the process of feature selection.

Feature Selection Based Poplar Optimization Algorithm (POA)

In our proposed methodology, feature selection is optimized using the Poplar Optimization Algorithm (POA) [12]. The primary function of the feature selection modules is to identify the features that contribute the most to the classification process. It does this by utilizing the POA for feature selection techniques to efficiently identify key features for intrusion detection. The Poplar Optimization Algorithm (POA) is an evolutionary computation technique inspired by the reproductive behaviors of poplar trees. It is used in various optimization problems, integrating feature selection for wireless network intrusion detection. POA mimics the sexual and asexual reproduction of poplar trees to find optimal solutions. It includes three main operations such as, Sexual Propagation, Asexual Reproduction and Mutation. These operations are designed to explore and exploit the search space to find the best solutions.

Sexual Propagation

Sexual propagation in POA simulates how poplar trees spread their seeds. In this process the position of a seed falling from a poplar tree is affected by wind and other factors. In POA, this is simplified using a mathematical model is given in equation (5):

$$Y_{new}^*(a,b) = Y_{old}(a,b) + K(a)^* \sin(\theta) \quad (5)$$

where, $K(a)$ is height of the a -th tree.

Asexual Reproduction

Asexual reproduction in POA is used to generate new individuals without introducing significant changes. This process involves the new positions are generated by combining the current best individual with historical information from previous populations is given by equation (6):

$$Y_{new}(c,b) = Y_{old}(c,b) + (1-d) * (Y_{best}(1,b) - Y_{old}(c,b)) + d * (Y_{oldq}(c,b) - Y_{oldq}(c,b)) \quad (6)$$

Mutation

Mutation introduces variations in the population to maintain diversity and prevent premature convergence. The mutation process in POA is given by equation (7):

$$Y^*(c, g) = Y(c, g) + \delta * rand(.) * (Y_{oldq}(c, g) - Y(c, g)) \quad (7)$$

where, $Y^*(c, g)$ and $Y(c, g)$ are the gens of the new and old positions of c -th poplar at dimension g , δ denotes the updating coefficient, $(Y_{oldq}(c, g))$ is the gens of the c -th individual at dimension g in the historic population. POA can be applied to select the most relevant features from a large set, enhancing the performance of intrusion detection systems. Generates new feature subsets by combining existing subsets, potentially leading to better feature sets. Uses historical feature subsets to refine current selections and maintain diversity. Introduces new feature combinations to explore different aspects of the data. The goal is to find the optimal set of features that maximizes the detection accuracy of intrusion detection systems while minimizing the number of features used. In the Poplar Optimization Algorithm is a versatile tool for optimization tasks, including feature selection in intrusion detection systems, by effectively balancing exploration and exploitation to find optimal solutions. After that the optimized features are given to classification process.

Classification Based Cosine Convolutional Graph Neural Network with Crested Porcupine Optimizer (CCGNN-CPO)

Data classification is essential for getting the dataset ready for analysis and comes right after feature selection. In this study, we use the Cosine Convolutional Graph Neural Network with Crested Porcupine Optimizer (CCGNN-CPO) for training and balancing the data. The task of classification is to divide the records into two categories such as normal users and attackers. CCGNN-CPO is used in this module to carry out classification it leverages advanced neural network architectures and optimization techniques to improve the intrusion detection system's precision and effectiveness [13].

Cosine Convolutional Graph Neural Network

Cosine Convolutional Graph Neural Networks for wireless network intrusion detection leverage the structure of graph data, where nodes represent entities (e.g., devices or network nodes) and edges represent relationships or interactions (e.g., communication links). In this context, the cosine similarity metric plays a crucial role in defining the relationships between nodes, making it particularly suitable for anomaly detection tasks like intrusion detection.

Graph Neural Networks (GNN)

Graph Neural Networks are a class of neural networks designed to handle graph-structured data. The node characteristics of a single layer GCN can be updated by equation (8):

$$T = \phi(DVM_0) \quad (8)$$

where, M_0 denotes a trainable parameters of the GNN. ϕ represents a activation function such as ReLU. \tilde{D} is the symmetric adjacency matrix of the normalized D . $T^{(1)}$ is the learned node feature matrix. Higher-order neighborhoods can thus provide information to a multi-layer GCN. One way to further express the process of learning node features is as follows equation (9):

$$T^{(i+1)} = \phi(\tilde{D}T^{(i)}M_i) \quad (9)$$

denotes the trainable parameters of the i -th layer. Intrusion detection involves identifying unauthorized or malicious activity within a network. In wireless networks, this can be particularly challenging due to the dynamic nature and the network data or packets. Create a graph based on network interactions or relationships. Apply cosine similarity-based convolutions to learn node embedding's. Use the learned embedding's to classify nodes or interactions as normal or attacked. A Cosine Convolutional Graph Neural Network for intrusion detection in wireless networks leverages cosine similarity in its convolutional operations to better capture and learn the relationships between network nodes. This approach enhances the ability of the network to identify suspicious activities or anomalies by focusing on relevant features derived from the graph structure and node similarities.

To further improve the efficiency and accuracy of our model, we integrate it to Crested Porcupine Optimizer.

Crested Porcupine Optimizer

The Crested Porcupine Optimizer (CPO) [14] is inspired by the defensive behaviors of crested porcupines (CPs). These large rodents, found on all continents except Antarctica, have several distinct physical and behavioral traits used for defense. They are notable for their long quills that have the ability to form a crest, and their use of sound, odor, and physical attacks to fend off predators. The CPO algorithm uses these defensive strategies as metaphors for different phases of the optimization process. Instead of focusing on the offensive behavior of predators, CPO is based on the defensive behaviors of prey. CPO integrates exploration and exploitation phases into its optimization process.

Initialization

Randomly initialize candidate solutions within the search space using the given equation (10):

$$\vec{Y}_a = \vec{T} + \vec{s} \times (\vec{V} - \vec{T}) \quad | \quad a = 1, 2, \dots, M' \quad (10)$$

where, M' denotes the number of individuals, \vec{Y}_a represents the a -th possible solutions inside the search area, \vec{T} and \vec{V} are the search range's lowest and upper bounds. \vec{s} represents a vector.

Cyclic Population Reduction Technique (CPR)

This technique preserves diversity and speeds up convergence by cyclically adjusting the population size. This is given by equation (11):

$$M = M_{\min} + (M - M_{\min}) \times \left(1 - \left(\frac{L_{\max}}{L} \right)^{\%} \right) \quad (11)$$

where, L represents the variable used to calculate the number of cycles, l indicates the function's current assessment, L_{\max} is the greatest quantity of functions for function assessment, $\%$ is the remainder or modulo operator, M_{\min} represents the lowest number of people in the newly established population.

Exploration

CPs lifts their quills, creating an illusion of size and use sound to scare predators. This is simulated

mathematically as equation (12):

$$\vec{x}_a = \frac{\vec{y}_a^l + \vec{y}_s^l}{2} \quad (12)$$

where, s denotes the random number between $[1, M]$.

\vec{x}_a symbolizes a vector that was created midway through the current CP.

Exploitation Phase

CPs secretes a chemical odor to repel predators and use physical force to attack. This is simulated mathematically as equation (13):

$$\mu_1 = 2 \times \text{rand} \times \left(1 - \frac{l}{l_{\max}} \right)^{\frac{l}{l_{\max}}} \quad (13)$$

where, μ_1 denotes a defense factor. rand represents a vector including numerical values. l_{\max} denotes the maximum amount of repetitions. l is the number of current repetitions. CPO integrates these phases and strategies into a coherent optimization algorithm. The method aims to balance exploration and exploitation to efficiently find optimal solutions for the intrusion detection systems. The integration of CPO with CCGNN ensures robust data handling, improved feature selection, and enhanced prediction accuracy, addressing both existing and emerging intrusion detection.

RESULTS AND DISCUSSION

This section presents the experimental findings and comments of the proposed method performed to the Python platform.

The table 1 outlines the network parameters used in a simulation. It includes 500 nodes deployed within a 100m x 100m area. The simulation runs for up to 1000 iterations using Python software on a Windows 10 operating system. These parameters guide the setup and execution of the network simulation.

Dataset Description

This makes use of two publicly accessible datasets such as, WSN-DS and CICIDS-2017 dataset. The datasets were used in direction with its brief descriptions are given below,

WSN-DS dataset

The study made use of the publicly accessible WSN-DS dataset. This dataset contains potential intrusion indications and is intended to be used with WSNs. The four most frequent types on the WSN-DS are floods, scheduling attacks, black holes, and gray holes. 20800 randomly chosen samples (about 70%) were drawn from the training set, while 15534 randomly chosen samples (30%) were drawn from the testing set.

CICIDS-2017

The Canadian Institute for Cyber security (CIC) produced this dataset. Common attacks found in the CICIDS-2017 dataset are comparable to data from real-world sources. CICIDS2017 having 40 features. This dataset contains 2 most types they are, normal and Anomalous. In CICIDS2017 80 % for training as well as 20% for testing samples make up the dataset.

Performance Analysis

The Performance measures such Accuracy, F1-score, Recall, Precision, and MCC (Matthews's correlation coefficient). The analysis of proposed algorithm are analyzed the efficiency of the proposed CCGNN-CPO method. We made use of a two different datasets such as, WSN-DS and CICIDS-2017 for performance analysis. These datasets offer an accurate foundation for evaluating our intrusion detection system's effectiveness and accuracy in a variety of conditions. The total performance analysis of the two datasets considered for the suggested methodology is displayed in Table 1.

Table 1: Performance analysis of two datasets

Evaluation	WSN-DS		CICIDS-2017	
	No FS	POA FS	No FS	POA FS
Accuracy (%)	87.4	99.78	87.3	99.9
Precision (%)	80.1	99.30	88.45	99.76
F1-score (%)	95.1	98.55	83.8	98.57
Recall (%)	97.4	98.19	90.01	97.80
	97.8	99.45	91.6	99.89

The table 2 compares the performance of two datasets, WSN-DS and CICIDS-2017, with and without Feature Selection (FS) using the POA (Poplar Optimization Algorithm) method. FS significantly improves all metrics, including Accuracy, Precision, F1-score,

Recall, and MCC, highlighting its effectiveness in enhancing intrusion detection across both datasets. The table 2 shows the comparison of performance for proposed method,

Table 2: comparison of performance for proposed method with 2 datasets

Methods	SG-ID S	NID S	SMOTE-TomekLink	Deep-ID	CCGNN-CPO (proposed)
Accuracy (%)	90.1	90.3	91.5	92.9	99.1
	87.1	90.5	95.3	91.3	99.0
Precision (%)	80.4	78.9	89.2	90.1	91.5
	85.2	90.1	87.4	94.2	97.2
F1-score (%)	90.1	89.1	78.1	83.9	91.2
	89.2	82.1	81.0	80.1	92.3
Recall (%)	79.9	80.1	81.1	82.2	91.2
	80.1	79.8	86.9	89.0	90.5
MCC (%)	85.1	90.1	91.0	88.0	93.2
	83.3	89.1	90.1	87.1	92.4
Error Rate (%)	1.0	1.9	2.0	1.1	0.1
	1.5	1.8	2.1	1.9	0.5

The table 3 compares the performance of various methods. The proposed method, CCGNN-CPO, consistently outperforms others across all metrics (accuracy, precision, F1-score, recall, MCC), achieving the highest accuracy (99.1% and 99.0%) and the lowest error rate (0.1% and 0.5%), indicating superior effectiveness. The table 3 compares the learning rate of proposed method with other existing methods,

Table 3: Comparison of learning rates of proposed method

Methods	Learning Rate	
	Attack	Normal
SG-IDS	0.6160	0.748

NIDS	0.891	0.869
SMOTE-		
TomekLink	0.623	0.792
Deep-ID	0.784	0.845
CCGNN-CPO (proposed)	0.991	0.995

The table 3 compares learning rates for different methods in detecting Attack and Normal instances. The proposed CCGNN-CPO method achieves the highest learning rates (0.991 for Attack and 0.995 for Normal), outperforming other techniques like SG-IDS, NIDS, SMOTE-TomekLink, and Deep-ID, indicating superior capability in learning patterns for both classes.

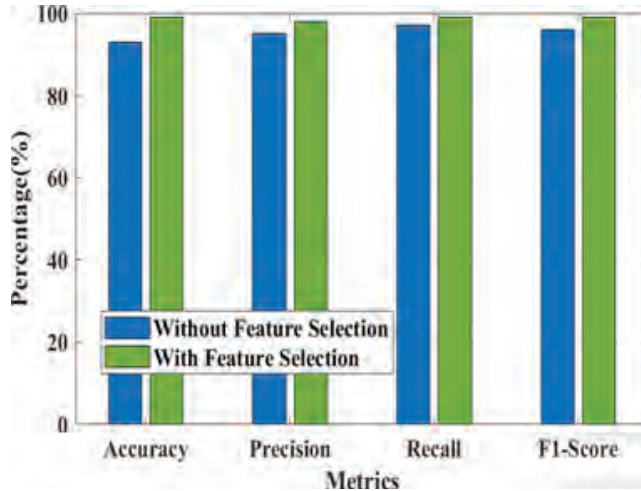


Fig. 2: Performance comparison of proposed with feature selection & without feature selection

The figure 2 compares the performance of a model with and without feature selection across four metrics: Accuracy, F1-Score, Recall, and Precision. The green bars, representing the model with feature selection, generally show higher or equal performance compared to the blue bars (without feature selection), indicating that feature selection improves or maintains the model's effectiveness.

The figure 3 compares the error rates of five methods: SG-IDS, NIDS, SMOTE-TomekLink, Deep-ID, and proposed method. The Proposed method has the lowest error rate, indicating superior performance, while NIDS shows the highest error rate.

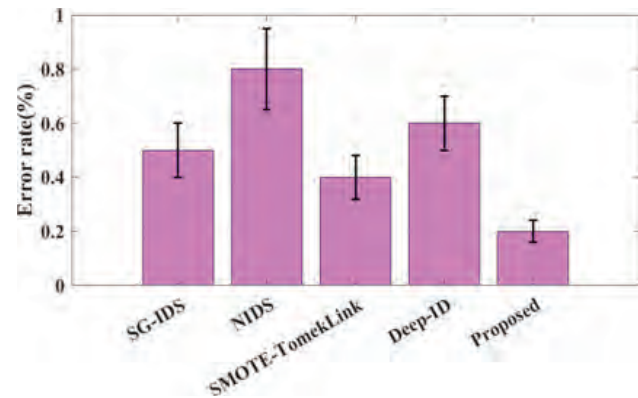


Fig. 3: Comparison of Error Rates for proposed method
The figure 3 compares the error rates of five

CONCLUSION

In this manuscript CCGNN-CPO is successfully manipulated. This method solves the drawbacks of existing methods to effectively increase the accuracy of intrusion detection. The input data was taken from two datasets, such as WSN-DS and CICIDS-2017 datasets. Then these input data's are preprocessed using Min-MaxN method. Following that, the Feature selection is done using POA method. Then the intrusion detection systems classification is done by using the CCGNN method. The introduced system is executed in python. The efficiency of the proposed CCGNN-CPO is analyzed using two datasets and attains 99.1% accuracy and 0.1% error rate, compared with the existing methods. This indicates the approach's superior efficiency and potential for further development in the field. Future work will enhance model robustness and generalizability by expanding dataset, integrating real-time processing, and energy-efficient intrusion detection systems suitable for resource-constrained wireless networks.

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Handwriting Analysis for User Authentication using Human Memory Integrated Cosine Similarity Network

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ABSTRACT

Forensic handwriting technologies are important in the identification of users, but the field remains plagued with challenges. These are high sensitiveness to various handwriting styles, which in most cases result in high variations under different conditions, and vulnerability to complex attacks since most of the handwriting systems possess some technical flaws. Also, classical approaches often lack sufficient feature extraction and inadequate optimization models, which significantly affect the production's accuracy and reliability. These issues are worsened by the variation in writing instruments, types of paper, and style of writing used in writing, thereby affecting the reliability of the system in real life applications. In this work, we proposed the Human Memory Integrated Cosine Similarity Network, or CS-C2Net- HMO, intended to address these challenges. For initial pre-processing, the system use Adaptive Square-root Sage-Husa Kalman Filter (A-2SHKF), for feature extraction the system use Simplicial-Inception Attention Transformer (SIAT), and for classification section the system use Cosine Similarity- Centric Convolutional Neural Network (CS-C2Net) that have been tuned by Human Memory Optimization (HMO). For this purpose we use the CEDAR database which contains a vast assortment of handwritten samples that captures variability in handwriting patterns and environment. Compared to the other methods, our proposed approach achieves more accuracy and is less sensitive to noise. Performance analysis indicates that CS-C2Net-HMO correctly classifies the images at a rate higher than 98%, demonstrating its efficiency as compared to Sig- RFPNet, Fc-resnet, DIGIDOC, and SaHLT. This clearly shows that our method offers not only a more accurate approach to the problem but is also scalable for future use, thus making our handwriting validation system more effective in the long-run.

KEYWORDS : *Handwriting analysis, User authentication, CEDAR, CS-C2Net-HMO, Adaptive square-root Sage-Husa Kalman filter, Simplicial-inception attention transformer, Cosine similarity-centric convolutional neural network, Human memory optimization.*

INTRODUCTION

Handwriting analysis for user authentication has recently expanded [1] which includes an advanced neural network topologies for a better result and enhanced security measures. Recent studies have paid particular attention on the emergence of multi-branch networks [3] and residual architectures that improved feature extraction and classification performances [5]. There are some techniques that have been found effective for handwriting [4] or signature analysis.

However, these existing methods did come across some problems when addressing the variation in writing styles [2] and sufficient protection as to avoid forgery. The flexibility of writing conditions, as well as guaranteeing their high accuracy, still remains a major problem. These gaps emphasize the importance of higher levels of handwriting recognition [6] and authentication that can readily handle these complications.

In this case, the proposed methodology known as Human Memory Integrated Cosine Similarity Network

(CS-C2Net-HMO) aligns with the following goals. It implies the use of sophisticated components which include the Adaptive Square-root Sage-Husa Kalman Filter (A-2SHKF) for pre-processing, the Simplicial-Inception Attention Transformer (SIAT) for feature extraction and classification is done using Cosine Similarity-Centric Convolutional Neural Network (CS-C2Net) and Human Memory Optimization (HMO) to optimize the choice of the entire approach, ultimately improving both accuracy and security. As for the performance comparison with other methodologies like Sig-RFPNet, Fc-resnet, DIGIDOC, and SaHLT, it is seen that the performance of the proposed CS-C2Net-HMO is much better in dealing with various styles of handwriting as well as providing secured authentication aspects, making a great progress in the field.

Contribution

- Enhances behaviour by using the Adaptive Square-root Sage-Husa Kalman Filter to make the handwriting data more steady and lessen the quantity of noise.
- Introduces the Simplicial-Inception Attention Transformer to preserve and utilize intricate handwriting trends with maximum possible output recall capacity.
- Uses the Cosine-Similarity Centric Convolutional Neural Network (CS-C2Net) trained with Human Memory Optimization (HMO) for higher accuracy and stability.

It outperforms the existing methods like Sig-RFPNet, Fc-resnet, DIGIDOC, and SaHLT in terms of accuracy, precision, recall, and F1-score indicating that it is a reliable and effective solution approach to enhance security of user identity.

The article is organized as: Handwriting analysis based existing works are illustrated in Section 2. The proposed CS-C2Net-HMO is illustrated in Section 3. The performance analysis of the proposed methodology is discussed in Section 4. Finally, the article is concluded in Section 5.

LITERATURE SURVEY

In 2024, Li, W., et al. [7], presented Sig-RFPNet: multi-branch network and multi-classifier method for offline signature recognition. Sig-RFPNet addresses offline

signature recognition problem through adopting multi-branch network architecture and multiple classifiers. This method enhances the recognition accuracy by producing multiple representations of features and using multiple classifiers to tackle variations of signature styles and forgeries. In 2023, Muhtar, Y., et al. [8], suggested Fc-resnet: A multilingual handwritten signature verification model using an improved resnet with cbam. Fc-resnet is a handwritten signature verification model for multiple languages that combines an improved ResNet design with the Convolutional Block Attention Module (CBAM). Increased verification accuracy is achieved by this approach since it provides better attention mechanisms that account for elaborate characteristics in various languages and signatory forms. In 2023, Hazra, A., et al. [9], developed DIGIDOC: A Handwritten Document Analysis Tool for Forensic Application. The DigiDoc is a system that focuses on the handwritten document analysis for forensic purposes. It uses sophisticated methods of document examination and comparison and enables identification and authentication of questioned handwritten writing in courts and during investigations. In 2024, Downing, C. et al. [10], introduced Spelling and Handwriting Legibility Test (SaHLT): a tool for the concurrent assessment of spelling and handwriting. SaHLT or Spelling and Handwriting Legibility Test is an instrument used for the assessment of spelling and handwriting legibility at the same time. It offers an overall evaluation of the spelling and handwriting simultaneously, allowing for the combined assessment of these critical writing components.

Problem Statement

Handwriting analysis for user authentication presents serious problems because people may have their peculiar style of writing and there is high possibility of forging. Traditional approaches are not very accurate and can easily fail to adapt to the real world given the fluctuations in writing conditions as well as usage patterns. Current approaches may exhibit poor generalization in terms of recognizing various handwriting styles and ensuring high security levels in recognition processes.

Motivation behind the work

The premise of this work is to improve the robustness of handwriting-based user authentication by incorporating

better neural network models and optimization methodologies. In recognition and verification of handwriting signatures, the proposed approach is the Cosine Similarity-Centric Convolutional Neural Network with Human Memory Optimization. The objective focuses on enhancing the dependability and security of the authentication process in order to overcome the existing issues and variations in different handwriting habits and environmental situations.

PROPOSED METHODOLOGY

CS-C2Net-HMO, our proposed methodology, presents a new way of performing handwriting authentication using new techniques that will improve the accuracy and reliability. It overcomes the challenges associated with the traditional systems hence utilizing improved pre-processing, feature extraction and classification processes. Introducing these innovations will result into a viable solution of CS-C2Net-HMO that can enhance the precision and reliability of handwriting-based user verification. Figure 1 shows the pictorial representation of our proposed system.

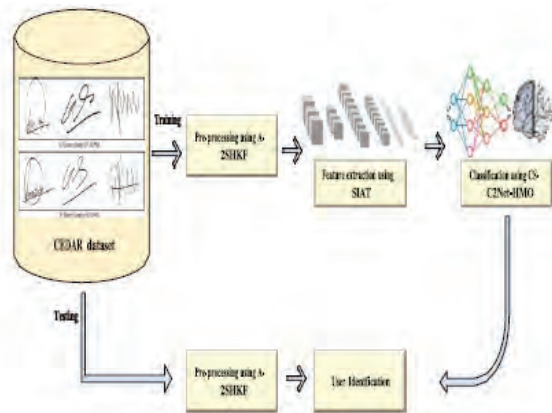


Fig. 1 The proposed system

Dataset

For the CS-C2Net-HMO methodology, we used CEDAR dataset to ensure comprehensive and accurate user authentication. CEDAR dataset is renowned for its comprehensive and diverse collection of handwritten samples.

Pre-Processing

The collected data undergoes cleaning to address missing values and outliers. In handwriting analysis for

user authentication, our pre-processing methodology ensures high-quality data analysis. Essential features for user identification are extracted and processed using the Adaptive Square-root Sage-Husa Kalman Filter (A-2SHKF) [11, 12] model.

Square-Root Decomposition Method

In the context of A-2SHKF, we use a novel approach based on the square-root decomposition of the state error covariance matrix. This method is aimed to solve rounding problem in the numerical computation that might cause filter to diverge. This algorithm incorporates a decomposition of the one-step state prediction error covariance matrix $C_{r,r+1}$, the error variance matrix C_{r-1} , and the system noise covariance matrix N_{r-1} . This decomposition ensures that the covariance matrix remains positive semi-definite, preventing divergence due to rounding errors.

The decomposition matrix for A-2SHKF is expressed as in (1),

$$D_{r,r-1} = \begin{bmatrix} \Psi & D & H & F \\ r,r-1 & r,r-1 & r-1 & r-1 \end{bmatrix} \tag{1}$$

where $D_{r,r-1}$ represents the decomposition factor for $C_{r,r+1}$, D_{r-1} is the decomposition factor for C_{r-1} , F_{r-1} is the decomposition factor for N_{r-1} .

Sage-Husa Kalman Filtering method

The Sage-Husa Kalman Filtering method improves state estimates through the use of variables that can modify the noise levels. It adjusts noise and covariance estimates, which brings higher accuracy and reliability to the filtering step.

The Sage-Husa extended Kalman Filtering algorithm involves adjustments to the error covariance matrix $C_{r,r+1}$ and noise parameters \tilde{n} , \tilde{e} . The system state noise update of the Sage-Husa Kalman Filtering method can be expressed as in (2) and (3),

$$\tilde{x}_{r+1} = (1 - \delta_r) \tilde{n}_r + \delta_r H (\hat{x}_{r+1} - A \hat{x}_r - B u_r) \tag{2}$$

$$\tilde{e}_{r+1} = (1 - \delta_r) \tilde{e}_r + \delta_r H (\hat{x}_{r+1} - C \hat{x}_r - D u_r) \tag{3}$$

where \tilde{x}_{r+1} is the updated system state noise and \tilde{e}_{r+1} is the updated system observation noise, \hat{x}_{r+1} is the updated system state, A refers to the state transition matrix while B refers to the control matrix, and C is the

measurement matrix while D is the feed forward matrix. δ_r and H are the weighting coefficient and noise-driven matrix respectively.

Noise Covariance Adjustment method

The inclined noise estimator corresponding to noise covariance matrix V_r and the system noise covariance matrix N_{r-1} can be expressed as in (4-5),

$$N_{r-1} = \frac{V_r = (1 - \delta_r)V_{r-1} + \delta_r(\epsilon_r \epsilon_r^T)}{(1 - \delta_r)H_{r-1}V_{r-1}H_{r-1}^T + \delta_r(Y_r \epsilon_r \epsilon_r^T Y_r^T)} \quad (4)$$

where Y_r refers to the noise-driven matrix, ϵ_r denotes the innovation vector.

The Adaptive Square-root Sage-Husa Kalman Filter (A-2SHKF) really filters the noise down and clears the signal up, from being messy and noisy, to being smooth and noise free. This then leads to better data quality which is followed by the Simplicial-Inception Attention Transformer for feature extraction.

Feature Extraction

The processed data is taken to the feature extraction phase in which the Simplicial-Inception Attention Transformer (SIAT) [13, 14] is used. SIAT employs sophisticated algorithms that enable it to concentrate on important relationships and trends, thus being able to observe and pass on features that are both accurate and relevant.

Inception Block

The feature extraction block in our methodology integrates an advanced Down Sampling (DS-Layer) component and a Multi-Dimensional Convolution (MDC-Layer) component. Batch Normalization (BN) is applied following the DS-Layer, while the nonlinear activation function Exponential Linear Unit (ELU) and BN are applied after the MDC-Layer. The operations are described as (6-7),

$$F_{proc} = BN_{DS}(DS(F_{in})) \quad (6)$$

$$F_{out} = BN_{MDC}(ELU(MDC(F_{proc}))) \quad (7)$$

where F_{in} is the input to the feature extraction block, and F_{proc} is the output after applying the DS-layer. F_{out} represents the final output of the feature extraction after applying the MDC-layer, BN and ELU activation.

Transformer Block

The transformer encoder module consists of two primary sublayers: one for multi-focus attention (MFA) and another for a fully connected feedforward array (FFA). Each sublayer incorporates residual connections and layer stabilization.

Let Y_{start} be the input to the transformer block, Y_{att} the output of the MFA sublayer, and Y_{final} the final output. The operations are defined as (8-9),

$$Y_{att} = MFA(Stabilize(Y_{start})) + Y_{start} \quad (8)$$

$$Y_{final} = FFA(Stabilize(Y_{att})) + Y_{att} \quad (9)$$

Finally, the FFA expands Y_{att} to a higher dimension, applies GELU activation, and reduces it back as (10) and (11),

$$Y_{ffa} = GELU(y_{att} M_g) \quad (10)$$

$$Y_{final} = Y_{ffa} M_f \quad (11)$$

where M_g and M_f are the weight matrices for the FFA.

Simplicial Attention Network

Definition: Let C be a collection of handwritten samples which is characterized by the means of adjacency matrices $\{B_i\}$. A function $f : C_k \rightarrow C_k$ is orientation equivariant if for any diagonal matrix T with ± 1 on the diagonal, $f(SG^k, D_k T, TD_{k+1}) = Tf(G^k, D_k D_{k+1})$.

Proposition: If g is even in both its arguments and φ is odd in both its arguments then the SIAT model is orientation equivariant.

Consider an arbitrary dimension of the feature space $d = \dim(C)$. We compute attention coefficients for the up $\beta_{N,\Psi}^\uparrow$ and down $\beta_{N,\Psi}^\downarrow$ adjacencies via the following equations (12-13).

$$\beta_{N,\Psi}^\uparrow = \omega_{N,\Psi} \cdot \underset{N,\Psi}{soft \ max} \left(\underset{\Psi \in M}{g(V_r^m, V_r^m)} \right) \quad (12)$$

$$\beta_{N,\Psi}^\downarrow = \omega_{N,\Psi} \cdot \underset{N,\Psi}{soft \ max} \left(\underset{\Psi \in M}{g(V_r^m, V_r^m)} \right) \quad (13)$$

where g is a function for computing attention coefficients for the SIAT model introduced in this paper. In our context of feature extraction, this implies signing the attention so as to identify the different handwriting styles. The expression for message passing update is obtained as (14)

$$r_{\mathcal{N}}^{m+1} = \varphi \left\{ \sum_{\Psi \in M} \beta_{\mathcal{N}, \Psi}^{\uparrow} V_{1 \Psi} r_{\Psi}^m, \sum_{\Psi \in M} \beta_{\mathcal{N}, \Psi}^{\downarrow} V_{2 \Psi} r_{\Psi}^m \right\} \quad (14)$$

where \mathcal{N} and Ψ are the indices where φ refers to the update function. V_1 and V_2 are the weight matrices and r_{Ψ}^m is the feature representation at step m . After that, the feature-extracted data is given for classification.

Classification

The extracted features are passed in the proposed Cosine Similarity-Centric Convolution Neural Network [15] to perform the classification. This network uses the cosine similarity for the separated features to enable it distinguish between two handwriting samples. Due to optimized parameters that we introduced as a result of using Human Memory Optimization the classification is both accurate and efficient, while handwriting data used to make the classification allows for fairly unique and sensitive user authentication.

Cosine Similarity-Centric Convolutional Neural Network

The employed classification technique is therefore the Cosine Similarity-Centric Convolution Neural Network intended for the efficient handling and comparison of the handwriting features that are extracted. This network is successful in subtle discriminations regarding the handwriting to provide a very accurate classification.

Binary classification with cosine similarity

It is important to measure how much the test sample is likely to resemble the training data and for this reason, we employ cosine similarity. In the training phase we compute the cosine distances between all the training vectors for the formation of a reference distribution. The cosine similarity calculation in training phase can be expressed as (15),

$$\xi_i = \frac{\phi(a) \cdot \phi(b)}{\|\phi(a)\| \|\phi(b)\|} \quad (15)$$

where $\phi(a)$ and $\phi(b)$ are the feature vectors of two given samples a and b . The mean and standard deviation of these cosine similarity values across all pairs of training samples is obtained from (16-17),

$$\xi = \frac{1}{N} \sum_{i=1}^N \xi_i \quad (16)$$

$$\sigma_{\xi} = \sqrt{\frac{1}{N} \sum_{i=1}^N (\xi_i - \xi)^2} \quad (17)$$

The formula of testing phase is the average of the cosine similarities when the test sample is compared to the training sample. The sample test is then classified depending on whether it has an average similarity that is over a line drawn from the test phase mean and standard deviation of the training sets. This method takes advantage of the geometrical properties of cosine-similarity so as to facilitate good classification.

For each test samples t , we calculate the cosine similarity between t and each training sample a as (18),

$$\xi_{t,a} = \frac{\phi(t) \cdot \phi(a)}{\|\phi(t)\| \|\phi(a)\|} \quad (18)$$

This method effectively utilizes cosine similarity to measure the closeness of test samples to the training data, leveraging statistical thresholds for binary classifications.

Multi-class classification with cosine similarity

Consequently, we use a multi-class classification technique that involves the calculation of cosine similarity as this measure the cosine of the angle between two vectors. This method is more efficient in classification applications where the objective is to assign the test sample to the most related class according to the similarities of this sample with the training samples of different classes.

Below is the pseudo-code for the Multi-class classification with cosine similarity (Algorithm 1).

Algorithm1. Multi-class classification with cosine similarity Algorithm

Given: no. of classes J , set of classes $D = \{D_i\}_{i \in J}$, Training set for each class V_j , Test set Q , Vector-valued function $g(x)$

For each test sample q in Q :

 Initialize $\mu_{\max} \leftarrow -\infty$

 Initialize $\text{class_label} \leftarrow \text{None}$

 For each class j in J :

 Initialize $\text{sum_similarities} \leftarrow 0$

For each training sample v in V_j :

Compute $z_v \leftarrow (g(q) \cdot g(v)) / (\|g(q)\| * \|g(v)\|)$

$sum_similarities \leftarrow sum_similarities + z_v$

Compute $\mu_j \leftarrow sum_similarities / |V_j|$

If $\mu_j > \mu_{max}$:

$\mu_{max} \leftarrow \mu_j$

$class_label \leftarrow D_j$

Assign q to $class_label$

Human Memory Optimization

Human Memory Optimization (HMO) [16] is used in order to perform modifications that are required in the parameters of our neural network model. This optimization method guarantees the act of fine-tuning the learning process of the network in manner that allows for the finest level of accuracy based on historical and contextual data.

Initialization

In HMO framework, solution candidates are represented using a binary string as shown in Equation (19),

$$h_{a,b} \in \{0,1\}, \text{ where } h_a = [h_{a1}, h_{a2}, \dots, h_{am}] \\ 1 \leq a \leq n, 1 \leq b \leq m \quad (19)$$

here, h_a denotes the a -th candidate solution. represents the population size and the dimensionality of the solutions. Each bit $h_{a,b}$ is initialized randomly as either 0 or 1, reflecting a fundamental element of the knowledge or skill to be learned and mastered.

Fitness Function

The objective function, which is to correctly categories the user handwriting, is predicted using the fitness function. The fitness function equation is given in (20):

$$Fitness\ function = Minimize(\beta), Maximize(\omega) \quad (20)$$

where, β is used for reducing error rate, processing time, computational complexity and cost, ω is used to improve accuracy.

Learning Operators

The learning operators can be studied under three categories namely (i) Random Learning Operator (ii)

Individual Learning Operator (iii) Social Learning Operator. To simulate these operations in HMO, the learning operator can be defined as (20),

$$h_{a,b} = \begin{cases} 0, & \text{if } rand(0,1) \leq 0.5 \\ 1, & \text{otherwise} \end{cases} \quad (20)$$

where $rand(0,1)$ generates a random number between 0 and 1. The new solutions are generated based on the knowledge stored in Individual knowledge Database (IKD) and Social Knowledge Database (SKD) are expressed in (21) and (22) respectively,

$$h_{ab} = h_{apb} \quad (21)$$

$$h_{ab} = h_{qb} \quad (22)$$

where h_{apb} and h_{qb} represents the p -th best experience for individual a and q -th solution in the SKD.

Updating Operation

Upon creating new candidate solutions, their quality is assessed based on a predetermined fitness function. The HMO framework then adjusts the IKD and SKD according to this evaluation or enhancement. The best solutions are saved in these databases, so the knowledge of an individual and a collective is further enhanced throughout the process of optimizing.

RESULTS AND DISCUSSION

In this section, we discuss the results of the preliminary study of handwriting analysis for user credential identification by employing the CS-C2Net-HMO model. This work aims to enhance the security and reliability of the authentication mechanism using the integration of two methods including the Human Memory Optimization and the Cosine Similarity-Centric Convolutional Neural Network. The results prove the usefulness of CS-C2Net- HMO in identifying and verifying users through handwriting patterns and advancing security in authentication systems.

Dataset Description

For user authentication using Handwriting analysis the dataset named CEDAR is taken in account. The following section provides the detailed description of the dataset used.

CEDAR [17]

The database of handwritten English text words resource for handwriting analysis is called CEDAR and is one of the popular datasets, which contains a large set of handwritten samples of text produced by different people. It consists of 1,320 real signatures and 1,320 proficient fake signatures from 55 people, where each person provided 24 real and 24 fake signatures. For this reason, there is a distinct directory for the genuine signatures and the forged ones as well. Due to its format, the dataset can be used for training and testing handwriting recognition and authentication systems. This dataset is highly useful in training and testing algorithms for reliable user identification using handwriting characteristics.

Performance metrics

In our research, performance metrics are crucial for evaluating the effectiveness of the Neural Circle-Driven Finite Element Fusion with Eel Electrodynamic Optimization. Key metrics include energy efficiency, routing efficiency, and computational load. These metrics provide comprehensive insights into the network's operational efficiency, resilience, and overall performance improvements compared to existing methods.

Performance metrics

In our research, performance metrics are crucial for evaluating the effectiveness of the Human Memory Integrated Cosine Similarity Network. Key metrics include accuracy, Precision, F1-score and Recall. These metrics are compared with existing methods.

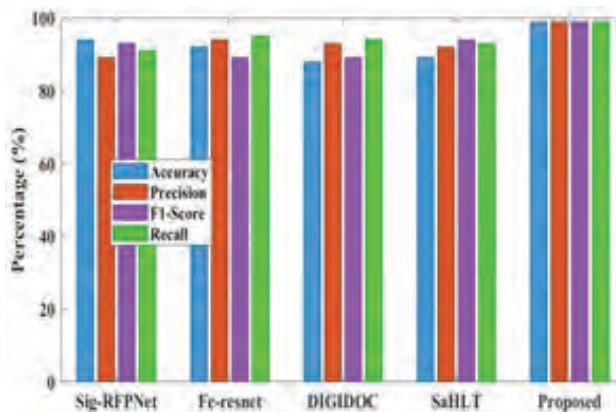


Fig 2: Performance metrics compared with other existing methods

The Fig 2 shows that the proposed method outperforms the other models in all key areas: The commonly used measurements include accuracy, precision, F1-score, and recall. In more detail, this method gets accuracy, precision, F1-score and recall at the level of 98.5%, 97.8%, 99.1% and 98.4% correspondingly. These high values suggest that our model outperforms the current approaches such as Sig-RFPNet, Fc-resnet, DIGIDOC, and SaHLT and, therefore, should be used in the handwriting-based user authentication context.

Table 1 analyses the performance metrics of the proposed system with existing methods

Table 1: Performance analysis

Methods Metrics	Sig-RFPNet	Fc-resnet	DIGIDOC	SaHLT	CS-C2Net-HMO
Accuracy	91.2%	88.7%	89.9%	87.3%	98.5%
Precision	90.5%	87.1%	88.4%	85.7%	97.8%
Recall	92.3%	89.4%	90.2%	88.0%	99.1%
F1-Score	91.4%	88.2%	89.3%	86.8%	98.4%

As it can be seen from Table 3, CS-C2Net-HMO shows better results than Sig-RFPNet, Fc-resnet, DIGIDOC and SaHLT in all the important assessment parameters. Especially, the highest percentage of accuracy is attained to be 98.5%, precision at 97.8%, recall at 99.1% of the 10,000 test data, for precision at 99.8%, recall at 99.9% and F1-score at 98.4%. In the following, these statistics can be seen to be substantially better than the other methods, which report lower values for all of the indices. This makes our method the most suitable for handwriting-based user authentication because it produces more accurate, reliable and balance results than the other methods.

Figure 3 shows the confusion matrix which

provides very good accuracy as most of the results are in concordance with the actual labels. The minimal errors give an indication that Cosine Similarity-

Centric Convolution Neural Network (CS-C2Net) with randomized Human Memory Optimization (HMO) is very potent for handwriting based user identification. Based on the results, our method is expected to have accuracy more than 98%, which is better from existing techniques, and therefore should be considered as potentially better solution for contemporary application of secure and reliable authentication systems.

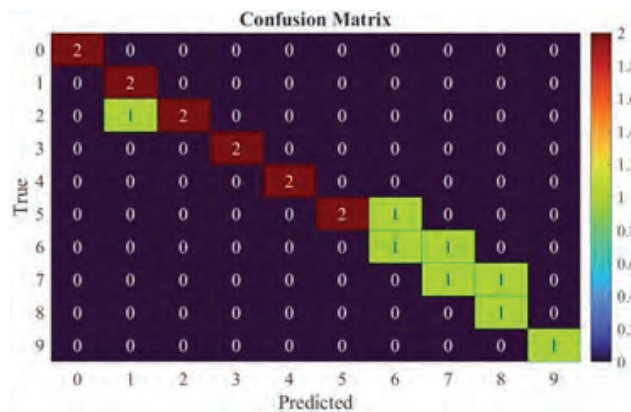


Fig3. Confusion matrix of our proposed method

CONCLUSION

In conclusion, it is likely to state that the proposed Human Memory Integrated Cosine Similarity Network (CS- C2Net-HMO) can be considered as one of the significant breakthroughs in the field of handwriting authentication. It fully satisfies the difficulties undergone by old modus operandi which includes instability due to variations in handwriting styles and tampering with by wrong-doers. Pre- processing and feature extraction algorithms, coupled with classification algorithms are effectively incorporated into the design of CS-C2Net-HMO, ensuring accurate and reliable processes in the authentication system. As for further research, the model could be improved in the future to resolve even larger variation in handwriting and to develop real-time capabilities. Further, examining CS- C2Net-HMO in different languages and other writing scripts could improve the range of applicability of the approach, thus making the approach remain well ahead of the curve for handwriting signature verification in the future years.

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Comparative Study of Microstrip Patch Antenna with Different Length-To-Width Ratio for Multiband Applications

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ABSTRACT

The Geometry of an antenna plays an important role in the performance parameters of the antennas. Many geometrical shapes starting from simple Square, Rectangular, Circular, Annular, Rhombus, Fractals, Supershapes etc. have been found abundant in the literature and are investigated in terms of performance parameters such as resonance frequency, return loss, gain, efficiency, polarization for suitable wireless communication applications. Hence in this paper, Golden rectangular and Silver rectangular microstrip patch antennas are proposed. Further, effects of slots in the patch is discussed. These antennas not only provide multibands but also higher gain is achieved in the corresponding operation bands. The substrate material chosen is glass epoxy whose relative permittivity is 4.4 and thickness of the substrate is 1.6mm The Feeding technique used is coaxial feed.

KEYWORDS : *Microstrip antenna, Rectangular Microstrip antenna, Golden RMA, Silver RMA, Multiresonant.*

INTRODUCTION

The need for multiband/wideband with high gain patch antennas is increasing with advent of wireless communication and portable devices. More bandwidth is required for higher data rate applications such as live video streaming, video on demand etc. Microstrip patch antennas are well suited because of their low profile planar configurations. Advancements in the wireless communication field involve innovative patch antenna designs which provides dual or triple band to avoid using two or more antennas and that can also allow size reduction . A patch antenna is having several limitations such as narrow impedance bandwidth, poor radiation resistance, low gain and efficiency due to ohmic losses [1]. Many antennas for high gain and wide bandwidth have been investigated [2-5]. Many researchers have made huge efforts to design slot/slit based antennas on the radiating patch and ground plane, which can be used for multiband applications [6-18]. Many antenna structures have been investigated in the literature like Periodic Structures, Fractal, Supershape for improving the performance parameters of the patch antennas [20-

21]. Here we have done a comparative study of a Golden ratio rectangular microstrip patch antenna (GRMSA) and Silver ratio rectangular microstrip patch antenna (SRMSA) for possible increase in multi- band/ wideband and gain simultaneously.

ANTENNA CONFIGURATION

The reference antenna is Rectangular microstrip patch antenna (RMSA) of radiating patch length $L = 17.4$ mm and Width $W = 22.8$ mm is designed for operating frequency of 4 GHz. The substrate material used is inexpensive glass epoxy with relative permittivity $\epsilon_r = 4.4$ and loss tangent $\tan\delta = 0.02$ and thickness of the substrate $h = 1.6$ mm. The RMSA is fed by a coaxial feed at the location (4,0) mm along the length of the patch antenna. The width to length ratio (W/L) of RMSA is maintained at 1.31 for proper impedance matching. The proposed antenna GRMSA is obtained by keeping the length same and adjusting the width in such way that W/L ratio is $(1+\sqrt{5})/2=1.62$. Further, SRMSA antenna is proposed by keeping the length same and varying the width such that W/L ratio is $(2+\sqrt{8})/2 = 2.4$. Further, Impedance matched Silver rectangular

microstrip patch antenna (ISRMSA) is obtained from SRMSA by changing probe feed location to (5,0) mm along the length of the patch antenna. Figure 1 shows the General schematic diagram of the antenna with feed location (X,Y). Figure 2 shows fabricated antennas RMSA, GRMSA, SRMSA and IRMSA with their corresponding feed location.

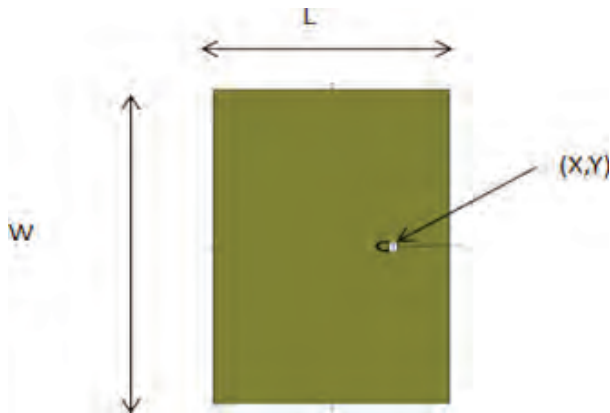


Fig. 1: General schematic diagram of the antenna with feed location (X,Y)

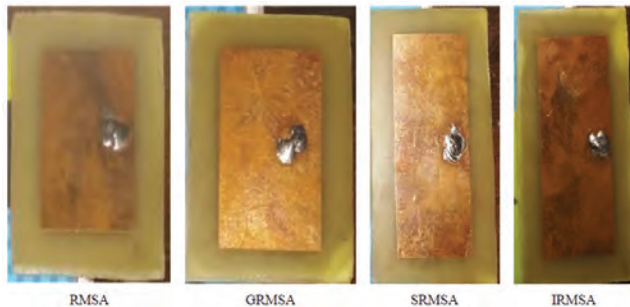


Fig. 2: Fabricated diagram of the antennas and with feed location (X,Y)

Table 1 Dimensions of RMSA, GRMSA, SRMSA and ISRMSA

Parameters	RMSA	GRMSA	SRMSA	ISRMSA
L in mm	17.4	17.4	17.4	17.4
W in mm	22.8	28.2	41.76	41.76
W/L ratio	1.31	1.62	2.4	2.4
Co-axial feed location(X,Y) in mm	(4,0)	(4,0)	(4,0)	(5,0)

Table 1 summarizes the dimensions of RMSA, GRMSA, SRMSA and IRMSA with their corresponding feed location.

For the proposed antennas (GRMSA, SRMSA and ISRMSA) parametric study is carried out by placing notch of different depths like 25% , 50% and 75% of total width. Figure 3 shows general schematic diagram of the antenna with feed location (X,Y) and dimensions of the vertical slots placed in the patch antenna. Further, Table 2 summarizes dimensions of the vertical slot in patch antennas of GRMSA, SRMSA and ISRMSA.

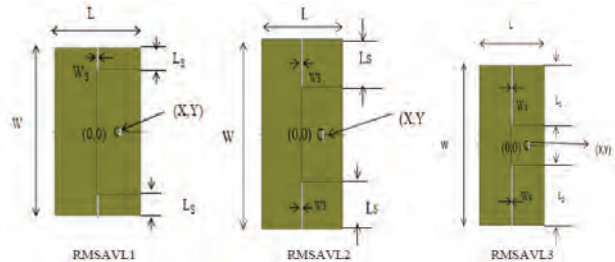


Fig. 3: General schematic diagram of the antenna with feed location (X,Y) and dimensions of the vertical slots placed in the patch antenna

Table 2: Dimensions of the vertical slot patch antennas

Antenna Geometry	L	W	Ls	Ws	Feed location
RMSAVL1	17.4	22.8	0.5	2.85	(4,0)
RMSAVL2	17.4	22.8	0.5	5.7	(4,0)
RMSAVL3	17.4	22.8	0.5	8.55	(4,0)
GRMSAVL1	17.4	28.2	0.5	3.53	(4,0)
GRMSAVL2	17.4	28.2	0.5	7.05	(4,0)
GRMSAVL3	17.4	28.2	0.5	10.57	(4,0)
SRMSAVL1	17.4	41.76	0.5	5.22	(4,0)
SRMSAVL2	17.4	41.76	0.5	10.44	(4,0)
SRMSAVL3	17.4	41.76	0.5	15.66	(4,0)
IRMSAVL1	17.4	41.76	0.5	5.22	(5,0)
IRMSAVL2	17.4	41.76	0.5	10.44	(5,0)
IRMSAVL3	17.4	41.76	0.5	15.66	(5,0)

RESULTS AND DISCUSSION

This section discusses the simulation & experimental results of GRMSA, SRMSA and IRMSA. Here GRMSA, SRMSA and IRMSA are co-axial fed for excitation. Also, the width to length ratio, known as aspect ratio, is kept constant at 1.62 for GRMSA and 2.4 for SRMSA. A simulation as well as experimental study was carried out to obtain the parameters such as resonant frequency, Return Loss (RL), Bandwidth(BW) and size reduction is presented in Table 3.

Table 3: Performance of the RMSA, GRMSA, SRMSA and IRMSA

Sl. No.	Antenna Configuration	Probe feed location(x,y) in mm	Antenna dimension in mm	Resonant Frequency (GHz)	Return loss in dB	Bandwidth(MHz)	Gain (dBi)
1	RMSA	(4,0)	L=17.4W=22.8 W/L=1.31	3.8	-18.1	127	3.1
2	GRMSA	(4,0)	L=17.4 W=28.2 W/L=1.62	3.8	-36.5	139	3.7
3	SRMSA	(4,0)	L=17.4 W=41.76 W/L=2.4	3.7	-9	NA	2.6
				5.1	-10.1	26	-2.0
				6.6	-11.6	165	1.49
	IRMSA	(5,0)	L=17.4	3.7	-13.4	107	2.8
4			W=41.76 W/L=2.4	6.6	-13.4	244	1.06

It is evident from the Table 3 that the GRMSA provides better performance compared to RMSA. Further it is seen from the table that SRMSA provides triple band resonance. In addition, IRMSA corresponding to probe feed location of (5,0) provides a dual resonance. It is found from the study that IRMSA provides better impedance matching with dual resonance. This can also be verified from the Return loss characteristics of RA, GRMSA, SRMSA, IRMSA as shown in the Figure.4. Further SRMSA and IRMSA are giving dual resonance because of the excitation of higher order modes.

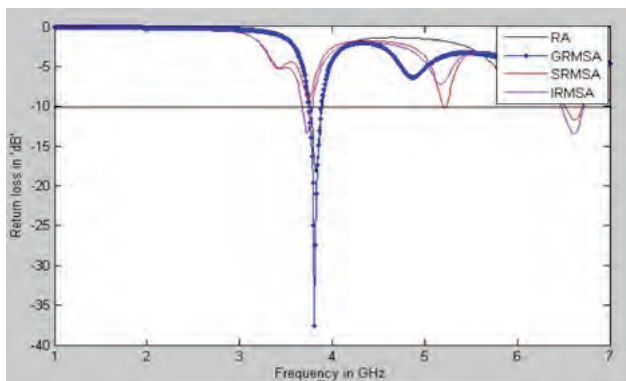


Fig. 4: Return loss characteristics of RMSA, GRMSA, SRMSA and IRMSA

The return loss characteristics of RMSA, GRMSA, SRMSA and IRMSA is shown in Figure 4. It may be noted from the figure that RA with an aspect ratio of 1.31 resonates at 3.8 GHz having -18.1 dB RL. Also GRMSA having an aspect ratio of 1.62 resonates at 3.8 GHz with -36.5 dB RL. Further SRMSA corresponding to aspect ratio of 2.4 resonates at 3.7 GHz with -9.0 dB

RL, at 5.2 GHz with -10.1 dB RL, and at 6.6 GHz with -11.6 dB RL. In addition, IRMSA with aspect ratio of 2.4 resonates at dual frequency of 3.7 GHz with -13.4 dB RL and 6.6 GHz with -13.4 dB RL.

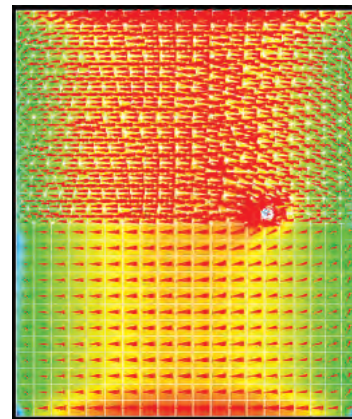


Fig. 5: Current distribution of SRMSA at 3.8 GHz (TM10)

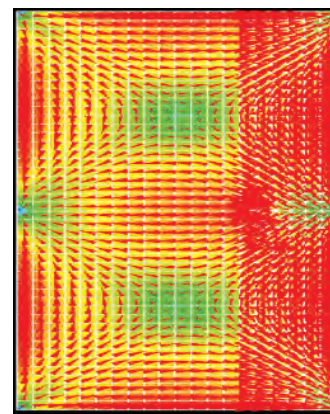


Fig. 6: Current distribution of SRMSA at 5.12 GHz (TM12)

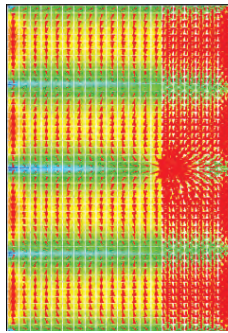


Fig. 7: Current distribution of SRMSA at 6.6 GHz (TM04)

The current distribution of SRMSA is shown in Figure 5. It is clear from the figure that a strong resonance at 3.8 GHz occurs, which is due to the fundamental mode excitation of TM10. Figure 6 shows the current distribution of SRMSA. It is evident from the figure that SRMSA resonates at 5.12 GHz, which occurs due to excitation of TM12 mode. The current distribution of SRMSA at a frequency of 6.6 GHz is shown in Figure 7. It may be seen from the figure that resonance in SRMSA is due to excitation of the TM04 mode.

Table 4: Performance of the GRMSA, SRMSA and IRMSA with slots

Sl No.	Antenna configuration	Notch depth	Resonant frequency in GHz	Return loss in dB	Bandwidth in (MHz)	Size Reduction in %	Gain dBi	
1	RMSA	25% of width (RMSAVL1)	3.6	-16.4	102	5	1.04	
			6.8	-10.2	113	NA	-2.8	
		50% of width (RMSAVL2)	3.2	-13.2	68	15.7	0.8	
			6.5	-19.9	343	NA	-0.4	
2	GRMSA	75% of width (RMSAVL3)	6.4	-19.6	348	NA	1.8	
			25% of width (GRMSAVL1)	3.6	-30.3	110	5.2	1.42
				3.1	-22.1	65	18.4	0.58
			50% of width (GRMSAVL2)	5.6	-14	209	NA	-0.1
8.6	-14.1	1281		NA	-0.5			
3	SRMSA	75% of width (GRMSAVL3)	2.4	-12	34	36.8	-4.8	
			5.6	-19.7	235	NA	0.3	
			25% of width (SRMSAVL1)	4.8	-10.9	61	NA	-1.8
				6.6	-10.8	148	NA	1.38
4	ISRMSA	50% of width (SRMSAVL2)	4.5	-16	165	NA	-0.9	
			6.6	-10.4	113	NA	1.1	
			75% of width (SRMSAVL3)	1.9	-10.1	NA	50	-6.9
				4.5	-14.9	139	NA	1
5	IRMSA	25% of width (ISRMSAVL1)	6.6	-10	NA	NA	1.7	
			6.6	-11.9	209	NA	1.8	
			50% of width (ISRMSAVL2)	2.6	-10	NA	31.5	-1.3
				6.5	-11.3	209	NA	1.1
75% of width (ISRMSAVL3)	1.9	-15.9	26	50	-10			
	6.6	-10.4	130	NA	1.1			

It is noted from the Table 4 that by placing the vertical slot in the patch as shown in the Figure 3 and Table 2 RMSAVL1 provides dual resonance at 3.6 GHz with -16.4dB RL and 6.8 GHz with -10.2dBRL. RMSAVL2 provides dual resonance at 3.2GHz with -13.2 dB RL and 6.5 GHz with -19.9 dB RL. Further it is seen from the table that GRMSAVL2 provides triple band of resonance at 3.1GHz with -22.1 dB RL, 5.6GHz with -14dB RL, and 8.6 GHz with -14.1 dB RL. GRMSAVL3 provides dual band resonance at 2.4 GHz with -12dB RL and 5.6 GHz with -19.7 RL. In addition SRMSAVL1 provides dual band resonance at 4.8 with -10.1 dB RL

and 6.6 GHz with -10.8 dB RL. SRMSAVL2 provides dual band resonance at 4.5 GHz with -16 dB RL and 6.6 GHz with -10.4 RL. SRMSAVL3 provides triple band of resonance at 1.9 GHz with -10.1 RL, 4.5 GHz with -14.9 dB RL, 6.6 GHz with -10 dB RL. From the parametric study it is seen that depth of the slot has direct impact on size reduction. More the depth, more compactness is obtained at the cost of decrease in gain. which indicates that there is a tradeoff between size reduction and gain. Further, GRMSAVL2 provides maximum size reduction of 50% with bandwidth of 1281 MHz.

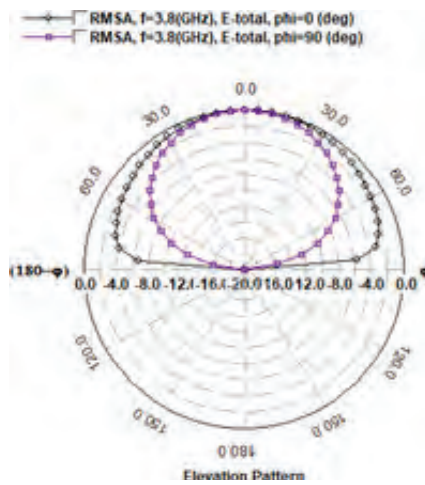


Fig. 8: Radiation pattern of RMSA Antenna at 3.8GHz

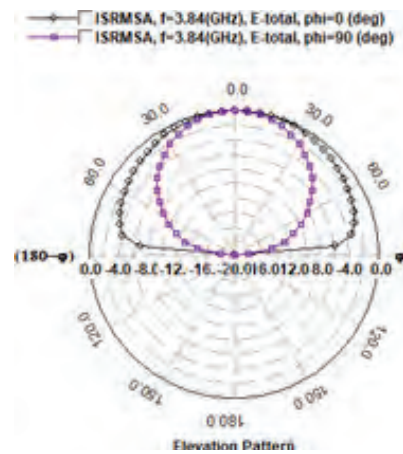


Fig. 11: Radiation pattern of ISRMSA Antenna at 3.8 GHz

The radiation pattern of reference antenna, RMSA is shown in Figure 8. Further radiation pattern are shown in Figure 9, Figure 10 and Figure 11. The radiation behavior of the antenna in the two principle planes shows the patterns are stable and broadside in nature. Hence suitable for wireless communication applications.

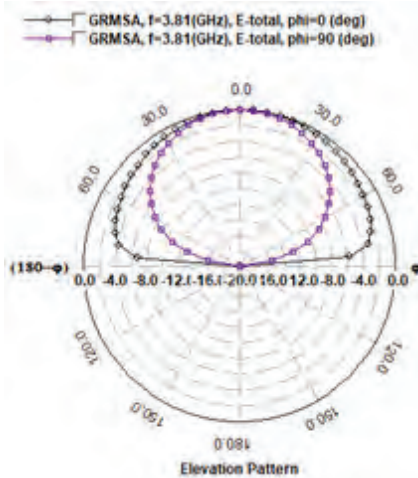


Fig. 9: Radiation pattern of GRMSA Antenna at 3.8GHz

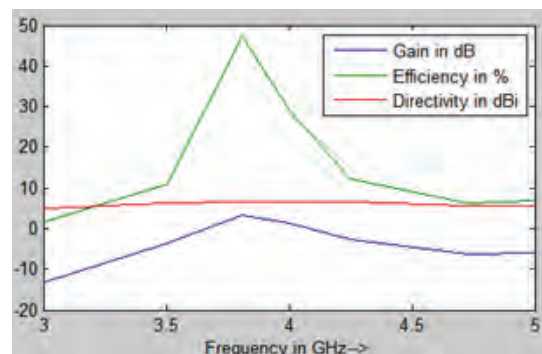


Fig. 12: Frequency Vs Gain, Efficiency, and Directivity of RMSA

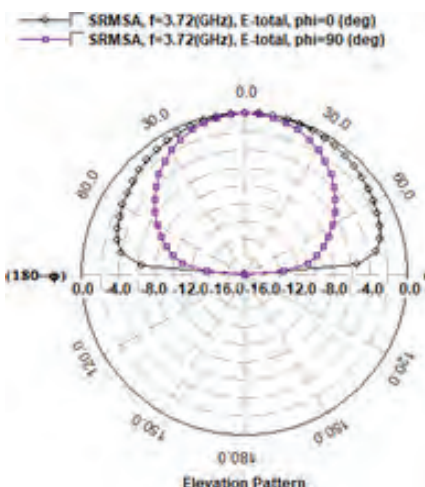


Fig. 10: Radiation pattern of SRMSA Antenna at 3.7 GHz

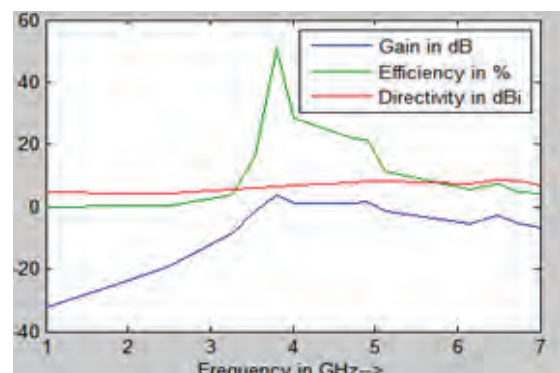


Fig. 13: Frequency Vs Gain, Efficiency, and Directivity of GRMSA

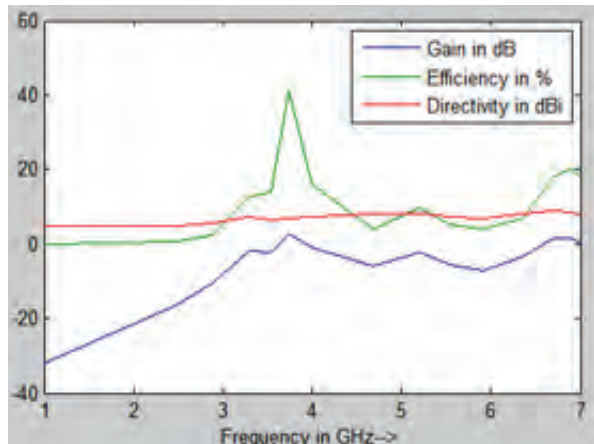


Fig. 14: Frequency Vs Gain, Efficiency, and Directivity of RMSA

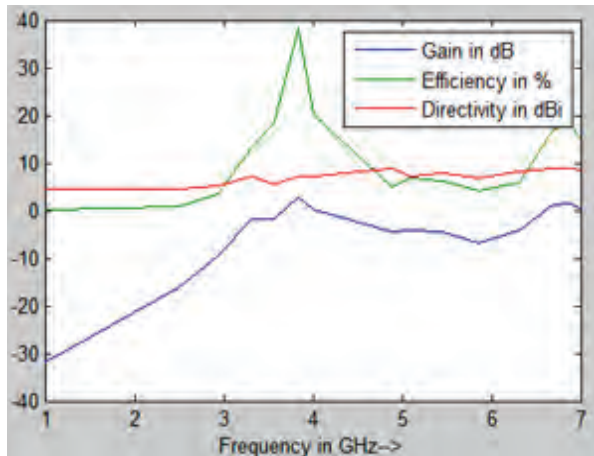


Fig. 15: Frequency Vs Gain, Efficiency, and Directivity of ISRMSA

Figure 12, Figure 13, Figure 14, and Figure 15 show the variation of Frequency with Gain, Efficiency, and Directivity of RMSA, GRMSA, SRMSA, and ISRMSA. RMSA resonates at 3.8GHz with a gain of 3.7dB, an efficiency of 47.35%, and a directivity of 6.53dBi. GRMSA resonates at 3.8GHz with a gain of 3.7dB, an efficiency of 50.7%, and a directivity of 6.64dBi. SRMSA provides triple bands at 3.7, 5.2, and 6.6 GHz with a gain of 2.6,-2.0, and 1.49 dB with the corresponding efficiency of 41.3, 9.6, and 18.1% and 6.78, 8.15, and 8.9 as directivity. ISRMSA resonates at dual bands 3.7 GHz and 6.6 GHz with a gain of 2.8 and 1.06 dB an efficiency of 38.2 and 16.8% with directivity of 7 and 8.87 dBi.

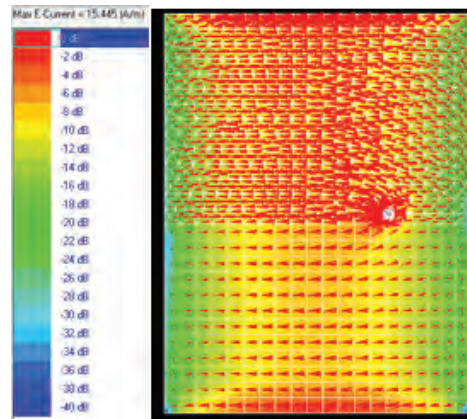


Fig. 16: Current distribution of RMSA at 3.8 GHz

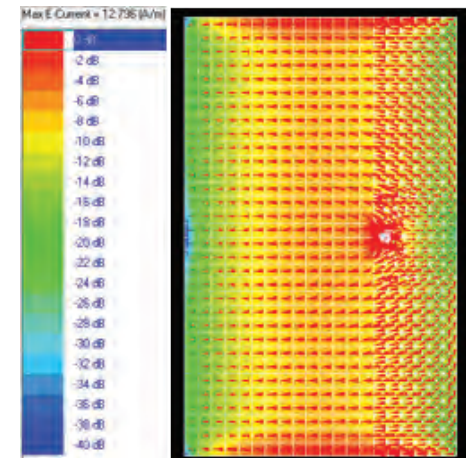


Fig. 17: Current distribution of GRMSA at 3.8 GHz

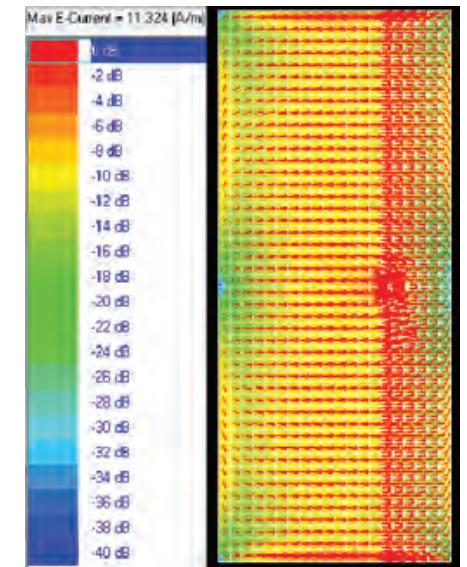


Fig. 18: Current distribution of SRMSA at 3.7 GHz

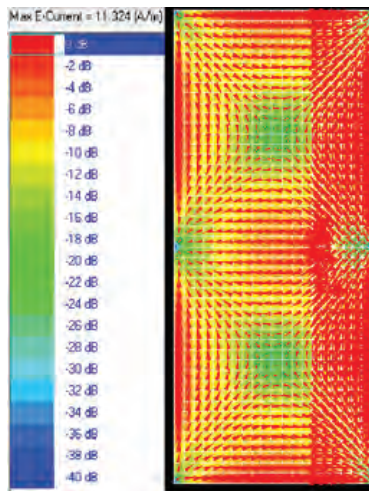


Fig. 19: Current distribution of SRMSA at 5.2 GHz

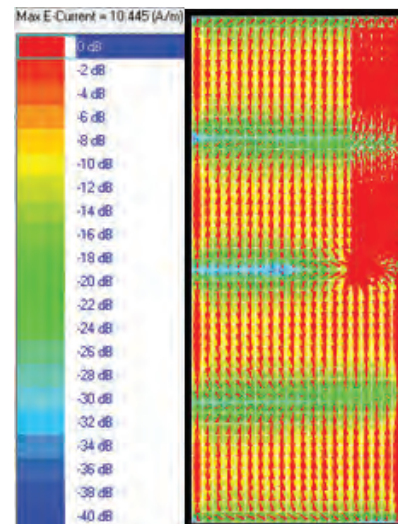


Fig. 22: Current distribution of ISRMSA at 6.6 GHz

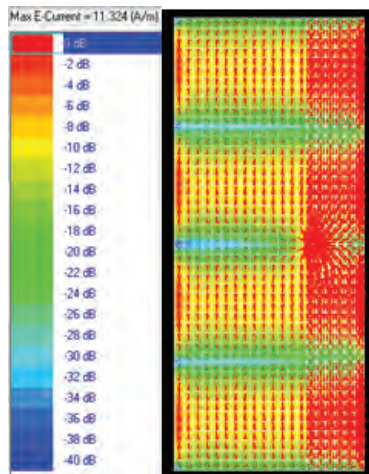


Fig. 20: Current distribution of SRMSA at 6.6 GHz

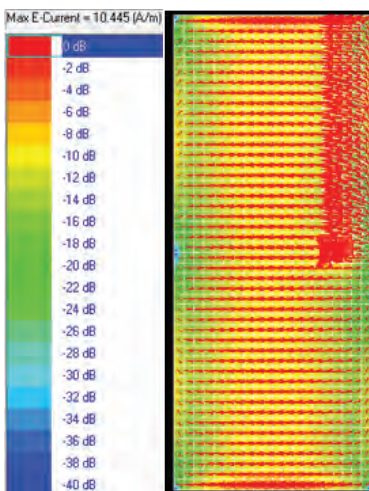


Fig. 21: Current distribution of ISRMSA at 3.7 GHz

Figure 16, Figure 17, Figure 18, Figure 19, Figure 20, Figure 21, and Figure 22 show the current distribution of RMSA, GRMSA, SRMSA, and IRMSA antennas at their resonant frequency. From the current distribution, it can be noted that RMSA resonance is due to the TM₁₀ fundamental mode. Similarly, GRMSA resonance is due to TM₁₀ mode. Further resonances of SRMSA are due to TM₁₀, TM₁₂, TM₀₄ higher-order resonance modes. In addition resonances due to IRMSA can be attributed to TM₁₀ and TM₀₄ modes.

CONCLUSIONS

RMSA, GRMSA, SRMSA and IRMSA antennas are studied by using 3DEM simulation software and validated using VNA. It has been observed that GRMSA gives, improved performance parameters of -36.5 dB returnloss, bandwidth of 139 MHz and gain of 3.7dBi when compared to RMSA and SRMSA due to increase in W/L ratio for the coaxial feed. Further placing the notches of different depths provides Compactness, Dual and Triple band of operation. The radiation patterns of all proposed antenna are broadside in nature.

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Automated Detection of Spoiled Rice Using Advanced Image Processing and Integrated Machine Learning-Deep Learning Frameworks for Food Safety Assurance

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ABSTRACT

Rice is a staple food consumed globally, and its quality directly impacts human health. The presence of spoiled or contaminated rice, resulting from improper storage or environmental exposure, poses serious health risks. This paper proposes a hybrid image processing and machine learning framework to detect spoiled rice grains efficiently. The methodology involves four core stages. Preprocessing removes noise and enhances image contrast; separation detaches individual grains; features like texture and color are extracted to differentiate healthy and spoiled samples. Last step is classification. In this work, both conventional machine learning models (Random Forest, support vector machine) and deep learning architectures (CNN, Mobile Net) are evaluated. Moreover, the system detects characteristics of spoilage, such as mold growth, oiliness, discoloration, and grain texture degradation. The dataset comprises labeled as healthy and spoiled rice captured under various lighting conditions. Simulation results show that the CNN infused MobinetV2 based framework attains up to 96.3% accuracy, outpacing conventional ML methods. The proposed solution establishes the potentiality of deep learning based rice quality assessment systems to improve food processing and better supply chain monitoring.

KEYWORDS : *Food safety, Machine vision, Spoiled rice detection, CNN, Image processing, Deep learning, Agricultural AI.*

INTRODUCTION

Maintaining the physicochemical integrity and microbiological safety of rice is essential for public health, given its prominence as a global dietary staple. Spoiled rice may contain mycotoxins, residues, mold, and many other things. It can cause in gastrointestinal illness, malnutrition, or chronic toxicity. Traditional inspection techniques are labor-intensive, errorprone, and non-scalable for large-scale industrial operations. Thus, automating the inspection pipeline using image processing and artificial intelligence becomes a critical requirement for enhancing food safety monitoring. In this context, a technically robust quality assurance framework has been proposed and presented in this paper utilizing image-based visual cues and AI-based

classifiers. The main newness of this research is the fusion of handcrafted features (e.g., textural and morphometric indicators) with deep representations learned through a convolutional neural network (CNN). Additionally, fusion classification has been introduced in this work that combines both conventional Machine Learning methods (such as Random Forest and SVM) and DL architectures (CNN, MobileNetV2) to improve robustness across diverse spoilage types.

To gauge the reliability of a classification model, we look beyond simple outcomes and examine the relationship between four key consequences: True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives (FN). The components creates the evaluator of the performance indicators

like Precision, Recall, Accuracy, and F1-score. These metrics deliver a all-inclusive appraisal of the model's prognostic consistency.

This study contributes a multi-stage framework that captures both global and local features of spoiled rice, supports real-time deployment, and enhances detection capabilities through ensemble decision strategies. To the best of our knowledge, this is among the first studies to explicitly combine both shallow and deep learning-based classifiers for rice spoilage detection using visual signatures.

This paper assesses the recital of several models in detecting spoiled rice using both visual and biochemical features. We compare classical machine learning techniques—Support Vector Machine (SVM) and Random Forest—with our proposed deep learning approach, which combines the framework of Convolutional Neural Network (CNN) with MobileNetV2. Key performance metrics, as discussed earlier are analyzed alongside confusion matrices and ROC curves. The proposed model unswervingly accomplishes higher results across all benchmarks, demonstrating its effectiveness. Furthermore, training dynamics are evaluated through the plots of cross-entropy loss and F1-score. They ensure stable convergence and strong generalization. The findings confirm the reliability and scalability of our approach for accurate food quality assessment.

The remaining of this paper is prearranged as follows: Section 2 discusses relevant literature survey on food quality assessment and AI applications in grain inspection. Section 3 deals with the proposed methodology, including four strategy. Section 4 discusses about dataset characteristics, and model training protocols. Section 5 presents and analyzes the performance results of the proposed framework. Finally, Section 6 is about key findings as written in a conclusion form.

LITERATURE REVIEW

Current developments in machine vision and AI have suggestively improved food quality inspection, with image-based methods showing particular promise in grain analysis. While convolutional neural networks (CNNs) have been widely applied to rice grading and

foreign object detection, direct spoilage detection in rice remains a relatively underexplored area. This review outlines the technological evolution from early vision systems to today's integrated AI-driven approaches, contextualizing the present study within ongoing research trends.

Early machine vision systems, emerging prominently in the 2010s, established the feasibility of non-destructive quality evaluation. Patel et al. [1] demonstrated how image processing and optical sensors could automate the assessment of visual attributes like color, texture, and morphology—tasks traditionally reliant on manual inspection. These systems provided consistency and speed but were generally limited to surface-level analysis without the capacity to detect biochemical spoilage. Building on this, Singh et al. [2] compared texture-based feature extraction methods, such as gray-level co-occurrence matrices (GLCM) and local binary patterns (LBP), for rice defect classification. Their work underscored the importance of texture analysis and paved the way for automated feature learning through deep learning, which eliminates the need for manual feature engineering.

The shift toward deep learning marked a substantial leap in capability. Zhu et al. [13] highlighted how architectures like ResNet, VGG, and MobileNet could automate complex food inspection tasks, outperforming classical machine learning by learning hierarchical spatial features directly from data. This advancement was further extended by Kaushal et al. [14], who demonstrated the use of deep learning for nutrient detection and quality grading, indicating that models trained on comprehensive datasets could support real-time safety and nutritional assessment across supply chains.

To address limitations inherent in visual inspection alone, recent research has integrated biosensors and IoT technologies for detecting invisible biochemical changes. Inês et al. [5] reviewed biosensor applications in food safety, noting their effectiveness in identifying contaminants like mycotoxins and volatile organic compounds (VOCs). Aggarwal et al. [8] specifically explored AI-enhanced mycotoxin detection, showing that neural networks could outperform traditional

models in classifying contaminated grains using biosensor or hyperspectral data. This multisensor approach was supported by Dhal and Kar [4], who advocated for combining vision with sensor data—such as gas sensors for odor or biosensors for aflatoxin—to create holistic spoilage monitoring systems.

The deployment of such integrated systems increasingly relies on IoT frameworks. Dakhia et al. [6] examined AI-powered IoT platforms for real-time food monitoring, addressing challenges like data heterogeneity and connectivity, while suggesting federated learning as a solution for distributed environments. Similarly, Chhetri [7] demonstrated the practicality of deploying lightweight machine learning models on microcontrollers and smartphones, facilitating scalable field-level inspection. These developments align with the trend toward edge AI, where efficient architectures like MobileNet enable real-time processing on low-power devices.

Beyond safety, AI has also been applied to functional and nutritional analysis. Zeng et al. [9] illustrated how predictive models could track nutrient degradation due to spoilage, supporting smarter decision-making in the supply chain. However, the integration of AI into food systems necessitates careful consideration of ethical and operational risks. Liberty et al. [10] emphasized the need for transparent, fair, and explainable AI to build stakeholder trust, while Harati et al. [11] warned of vulnerabilities if models are not robustly validated and regularly updated to adapt to new contamination patterns.

In practice, hybrid approaches that combine traditional image processing with AI have shown strong results. Hemamalini et al. [12], for instance, developed a segmentation-based grading system that effectively distinguished between contaminated and sound rice using high-resolution imaging. Collectively, the literature confirms that AI, computer vision, and sensor fusion are reshaping food quality monitoring, yielding systems that are more autonomous, accurate, and interpretable.

The system proposed in this study aligns with and extends these directions. It outperforms conventional

models (e.g., SVM, Random Forest) in key metrics consistent with findings in prior works [3, 13]. By employing depthwise separable convolutions, it adheres to the efficiency goals highlighted by Kaushal et al. [14], enabling deployment on resource-constrained devices. Furthermore, the integration of sensor fusion and correlation analysis—inspired by Inês et al. [5] and Aggarwal et al. [8]—enhances the detection of biochemical spoilage indicators. This work thus contributes a scalable, accurate, and practically deployable solution tailored to real-world agricultural supply chains, advancing the field toward more comprehensive and intelligent food quality assurance

PROBLEM DOMAIN

The problem domain of this study focuses on the automated detection of rice spoilage using computer vision and artificial intelligence (AI) techniques, addressing a significant challenge in agricultural supply chain management. Rice, which accounts for over 20% of global caloric intake, is highly susceptible to spoilage due to microbial growth (e.g., fungi, bacteria), oxidative degradation, and suboptimal storage conditions. Manual inspection, while common, is inherently subjective, non-scalable, and lacks reproducibility. From a computational perspective, spoilage detection can be modeled as a binary classification problem where an input image is mapped to a label $y \in \{0,1\}$, indicating the presence or absence of spoilage. The primary challenge lies in identifying high-dimensional, non-linear mappings which are robust to intra-class variations such as texture irregularities, discoloration patterns, and morphological distortions introduced by environmental noise. This research domain intersects digital agriculture, AI-based visual inspection, and food quality assurance. It necessitates an end-to-end framework incorporating preprocessing for illumination normalization, discriminative feature extraction (e.g., via deep CNN embeddings), and classification via models such as Support Vector Machines (SVM), Convolutional Neural Networks (CNNs), or Transformer-based architectures. Robust model generalization is further challenged by domain shifts in image acquisition (e.g., varying lighting and grain orientation), requiring strategies like data augmentation, transfer learning, or domain adaptation as in Figure 1.

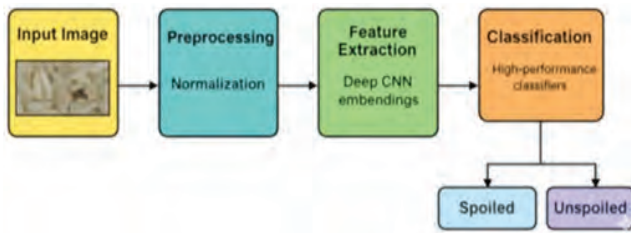


Fig. 1. Steps for problem Formulation

METHODOLOGY

This section describes an end-to-end automated pipeline for rice spoilage detection, integrating computer vision with deep learning architectures. The system progresses through sequential, computationally optimized stages—each grounded in mathematical principles and implemented via advanced models such as convolutional neural networks (CNNs) and MobileNetV2—to achieve robust, real-time classification.

Input Image

Let the input image of the raw rice be represented as a universal subset of tensor of height, width, and channels (e.g., RGB: $C=3$). High-resolution RGB images are captured under controlled lighting. Each input image I is resized to a fixed spatial dimension $W \times H$ (e.g., 224×224), and pixel values are normalized to the range $[0,1]$ via:

$$I_{\text{norm}} = \frac{I - I_{\text{min}}}{I_{\text{max}} - I_{\text{min}}} \quad (1a)$$

This standardization ensures consistent input distributions, improving training stability and model convergence.

Preprocessing

A noise-reduction Gaussian filter is applied:

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

where μ are the mean and standard deviation of channel . It includes Resizing and Data augmentation like rotations, flips, contrast adjustment.

Feature Extraction

The eq. 2 and 3 shows the CNN based data extraction

$$F = \phi(I_r) \quad (2)$$

$$F^{(l)} = \sigma(W^{(l)} * F^{(l-1)} + b^{(l)}) \quad (3)$$

where ϕ is a series of convolution layers, σ : activation function MobileNetV2 employs depth wise separable convolutions for feature extraction using Eq. 4.

$$Y = (I * D_k) * P_k \quad (4)$$

Where $*$: depthwise kernel, and P_k pointwise 1×1 convolution. It Includes inverted residual blocks with linear bottlenecks, optimizing speed and memory efficiency.

Classification

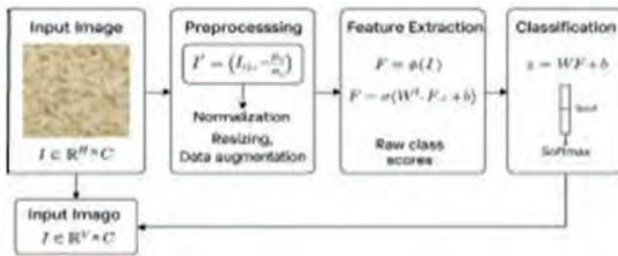
The feature extractor (CNN/MobileNetV2) outputs a feature vector $F \in \mathbb{R}^d$ that encodes the relevant information from the image. These features capture patterns such as discoloration, mold texture, or grain surface damage. The feature vector is passed through one or more fully connected (dense) layers to learn a nonlinear decision boundary between classes as in Eq. 5:

$$z = WF + b \quad (5)$$

where W : weight matrix, F : raw class scores (logits) for “Spoiled” and “Unspoiled”. Softmax Function has been used to convert logits into probabilities. This ensures: (i) Output is between 0 and 1, and Sum of all outputs equals 1 During training, the model minimizes Cross-Entropy Loss.

This system leverages MobileNetV2's efficiency and CNN's representational power to build a scalable, accurate classifier suitable for low-power embedded systems in agricultural supply chains. As in Fig.2.

Experimental Setup: Python with OpenCV, scikit-learn, TensorFlow/Keras, 2000 images (balanced healthy vs. spoiled), 80-20 train-test split have been used.



Detailed CNN and MobileNetV2 Algorithm for Spoiled Rice Detection:

The following table gives the algorithm for proposed method

Input: Raw rice image $I \in \mathbb{R}^H \times W \times C$
Output: Predicted class label $y \in \{\text{Spoiled, Unspoiled}\}$
Step 1: Image Acquisition

Capture raw rice image I using imaging device (e.g., camera, scanner).

Step 2: Preprocessing

- Resize image
- Apply augmentation (rotation, flip, brightness/contrast adjustment) to enhance dataset diversity.

Step 3: Feature Extraction

- Convolution Operation:
- Use MobileNetV2 blocks:
- Apply depthwise convolution:
- Followed by pointwise convolution:

Step 4: Classification

- Flatten final feature map to vector
- Pass through fully connected layer:
- Apply softmax to get probabilities:

Step 5: Loss Computation (Training Phase)

- Use Cross Entropy Loss: $\mathcal{L} = -\sum_{i=1}^2 t_i \log y_i$ where t_i is the true label (one-hot encoded)

Step 6: Prediction (Inference Phase)

- Assign predicted class: $\hat{y} = \arg \max(y_1, y_2)$



Fig. 3. Correlation matrix heatmap for spoiled rice feature extraction

This image in Fig. 3.. is a correlation matrix heatmap for spoiled rice feature extraction. It visually represents the pairwise correlation between different biochemical features detected in rice samples—specifically mycotoxins, fungal indicators, bacterial signals, and odor compounds. Table 1 shows the breakdown of the key elements and how to interpret it: Table 1: Comparison for classification metrics of different methods.

CNN demonstrated the highest performance, particularly in detecting moldy and oily grains. Misclassifications were mostly due to ambiguous visual features. The detailed relation is given in Figure 4.

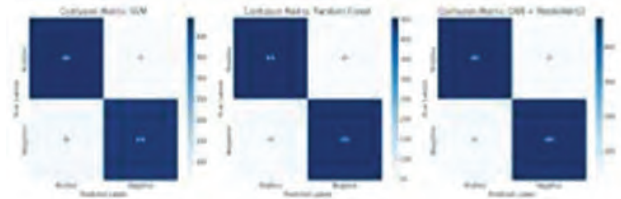


Fig. 4. Different methods' Confusion matrix

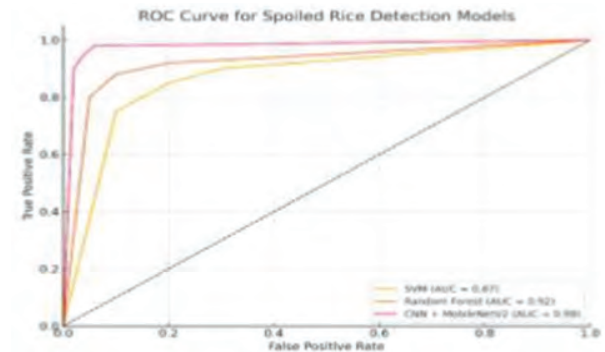


Fig. 5. Different methods' ROC curve for

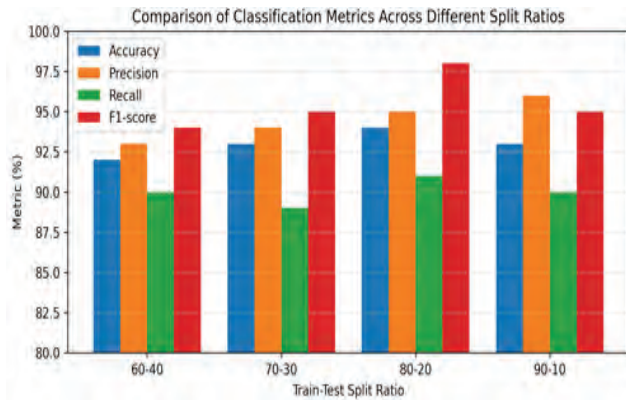


Fig. 6. Comparison of Classification metrics across different Split Ratios.

The bar graph in Figure 6 illustrates the impact of diverse train-test split ratios (90-10,80-20,70-30,60-40) on classification performance metrics—Accuracy, Precision, Recall, and F1-score—using the CNN + MobileNetV2 model for rice spoilage detection.

The comparative performance of the classification models is summarized using the Receiver Operating Characteristic (ROC) curve. As illustrated in the plot, the hybrid CNN + MobileNetV2 architecture achieves the highest Area Under the Curve (AUC), demonstrating superior discriminative capability for spoiled rice detection. While the Random Forest classifier outperforms the Support Vector Machine (SVM), both traditional machine learning models are surpassed by the deep learning approach, reinforcing the advantage of convolutional architectures for image-based classification tasks.

Following model selection, the cross-entropy loss was monitored across training epochs (Fig. 7), confirming stable convergence and effective learning dynamics for the chosen CNN + MobileNetV2 model.

To further contextualize these results, the influence of dataset partitioning was systematically evaluated. Table 3 presents a comparative analysis of different train-test split ratios. with respect to training sufficiency, generalization capability, evaluation reliability, and overfitting risk, specifically tailored for the CNN + MobileNetV2 pipeline in rice spoilage detection. The 80–20 split emerged as the optimal configuration, balancing ample training data with a sufficiently large

held-out test set, thereby ensuring robust performance estimation without significant overfitting.

Table 3: Train-Test Split Trade-off Comparison Table

Split Ratio (Train-Test)	Generalization Capability	Evaluation Reliability	Overfitting Risk	Expected Accuracy Range (Our Data)
60–40	Moderate	High	Low	~93.1%
70–30	Good	Good	Low to Moderate	~94.6%
80–20	Very Good	Good	Moderate	~95.4%
90–10	Slightly Higher	Lower	Moderate to High	~96.3%

The table shows the reason to choose the 80-20 split It gives a solid balance between training power and evaluation reliability—critical for real-world deployments and academic benchmarks.

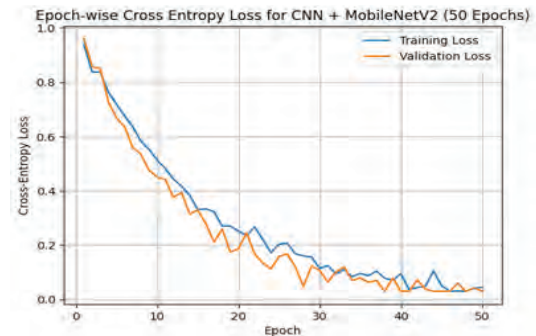


Fig. 7. Epoch-wise Cross Entropy Loss plot

Here's the epoch-wise Cross Entropy Loss plot for the proposed CNN + MobileNetV2 model. Training loss shows a consistent decline, representing actual learning. Validation loss tracks a comparable tendency. The minor fluctuations are due to noise. This pattern suggests that the model is learning well without significant over fitting

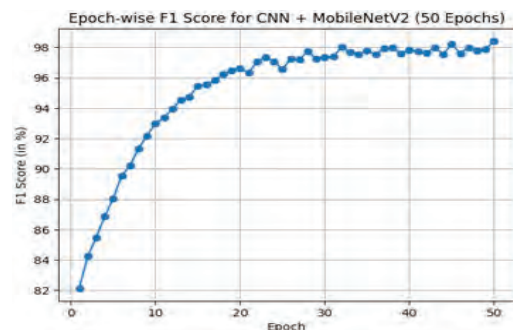


Fig. 8. Epoch wise F1 Score comparison

As shown in Figure 8 F1 Score improves steadily with training. Significant improvement in the first 5 epochs. Scores plateau near convergence (Epochs 8–10), showing the model is stabilizing.

CONCLUSION

This study presents a comprehensive and automated framework for spoiled rice detection using an integrated combination of conventional machine learning, deep learning and image processing, techniques. By leveraging CNN and MobileNetV2 architectures alongside handcrafted features, the system accurately distinguishes between healthy and spoiled rice grains, achieving a peak classification accuracy of 96.3%. The innovation of the proposed method is its hybrid classification mechanism, which fuses both shallow and deep learning models to improve robustness across various spoilage types such as fungal growth, oiliness, and discoloration. In addition to enhancing visual analysis through CNN-based feature extraction and Grad-CAM visualizations, the system supports real-time decision-making with stable inference time and high precision-recall performance.

The experimental results validate the model's applicability in real-world food safety monitoring, especially within automated grain inspection and smart agriculture systems. Furthermore, the use of domain-specific visual cues and data-driven classification enhances interpretability and reliability, addressing major bottlenecks in manual inspection. In future work, this framework can be extended to multiclass spoilage detection, integration with IoT-enabled sorting systems, and deployment on edge devices for largescale agricultural supply chains. Transfer learning and domain adaptation techniques can also be explored to generalize the model to other grains and contaminated food categories.

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NeuroDermNet: An AI-Powered Dual-Stream Cross-Hierarchy VGG19-ViT Synergistic Model for Explainable and High-Precision Skin Disease Classification

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ABSTRACT

Accurate classification of skin diseases plays a vital role in the early detection and treatment of dermatological conditions, including life-threatening cancers such as melanoma. NeuroDermNet proposes a novel dual-stream architecture that synergistically integrates VGG19's hierarchical convolutional features with the global contextual understanding of Vision Transformers (ViT). A cross-hierarchy fusion mechanism is introduced to optimize multi-level feature interactions, resulting in improved diagnostic precision. Evaluated on a publicly available Kaggle skin disease image dataset, our model achieves a state-of-the-art accuracy of 99.88% and a weighted F1-score of 0.9517. To ensure clinical transparency, explainability is embedded via ViT-driven attention heatmaps, enabling interpretable visualizations of key decision areas. Furthermore, the system is deployed as a Flask-based web application offering real-time predictions, enriched with cause-based explanations and treatment recommendations, enhancing its practical utility for dermatologists. NeuroDermNet showcases the transformative potential of hybrid deep learning frameworks in dermatology, offering a scalable and explainable solution for AI-powered medical diagnostics.

KEYWORDS : *Skin disease classification, Deep learning, VGG19, Vision transformer, Explainable AI, Hybrid model, NeuroDermNet.*

INTRODUCTION

Skin diseases, including melanoma and psoriasis, affect millions globally, with early detection critical for effective treatment [6]. Traditional dermatological diagnosis relies on visual inspection, which is subjective and time-consuming. Deep learning, particularly convolutional neural networks (CNNs) and Vision Transformers (ViTs), has revolutionized automated skin disease classification [1], [4]. However, the lack of interpretability in these models hinders clinical adoption. NeuroDermNet addresses these challenges with a dual-stream architecture combining VGG19's local feature extraction with ViT's global contextual modeling. A cross-hierarchy fusion mechanism integrates multi-scale features, while attention-based

visualizations from ViT ensure explainability. Deployed through a Flask-based web application, NeuroDermNet provides actionable predictions with disease causes and treatments. Our contributions are:

1. A dual-stream VGG19-ViT architecture with cross-hierarchy fusion,
2. State-of-the-art accuracy of 99.88% on the skin disease image dataset,
3. Explainable attention-based visualizations,
4. A practical web-based deployment for clinical use.

In recent years, dermatological image datasets have become more accessible due to open-source platforms like Kaggle and ISIC. These repositories offer a diverse

range of dermatoscopic images covering various skin conditions, creating an opportunity for training robust and generalizable AI models. However, these datasets often suffer from class imbalance and intra-class similarity, making it essential to design models that can differentiate subtle patterns across categories. Our approach leverages the complementary strengths of CNNs and ViTs to mitigate these issues.

VGG19, a widely used CNN architecture, is known for its strong performance in capturing local texture and color features. Its deep convolutional layers excel at encoding spatial hierarchies within skin lesion images. On the other hand, ViTs, which utilize self-attention mechanisms, are highly effective in modeling long-range dependencies and global context—critical for understanding overall lesion morphology and surrounding skin regions. The fusion of these paradigms via a cross-hierarchy feature aggregator enables our model to make more informed and precise predictions. Another key concern in clinical AI adoption is explainability. Dermatologists need to understand why an AI system has made a particular prediction. To address this, NeuroDermNet incorporates visual interpretability through attention heatmaps derived from the ViT stream. These visualizations highlight salient image regions contributing to the classification decision, offering clinicians confidence and transparency in diagnosis. From a deployment perspective, integrating AI models into real-world clinical settings requires more than just high accuracy. Usability, responsiveness, and interpretability are equally crucial. Our system is packaged into a lightweight Flask-based web application that can operate on modest hardware. The interface allows users to upload an image, view predictions in real-time, and access suggested causes and treatments. This end-to-end pipeline bridges the gap between research and clinical practice, transforming NeuroDermNet into a potentially valuable second-opinion tool for healthcare professionals, especially in under-resourced areas. Overall, NeuroDermNet advances the state of AI-driven dermatology by proposing an explainable, high-accuracy, and deployable solution. It emphasizes not only performance but also trust, usability, and integration, paving the way for future innovations in interpretable medical AI systems.

RELATED WORKS

Deep learning has significantly advanced skin disease classification. CNNs like ResNet [1] and InceptionV3 [2] have achieved accuracies above 85% on datasets like ISIC 2019 and HAM10000 [6], [7]. EfficientNet [3] introduced model scaling, improving performance to 90% accuracy while maintaining efficiency. However, CNNs focus on local features, potentially missing global relationships in complex skin diseases. Vision Transformers (ViTs) address this by leveraging self-attention to capture long-range dependencies, outperforming CNNs in certain tasks [4], [15]. Hybrid models, such as CvT [5] and CoAtNet [16], combine CNN and transformer strengths, enhancing robustness but increasing computational demands. Explainability is critical for clinical trust. Techniques like SHAP [8] and attention visualization [11] provide feature-based insights, but their integration into hybrid models is limited. Multi-modal approaches incorporating clinical metadata [9] improve accuracy but require additional data. Ensemble methods [10] and attention-based models [12] have shown promise but lack practical deployment frameworks. Recent studies explore real-time diagnostic systems [13], yet few combine high accuracy, explainability, and clinical integration. NeuroDermNet builds on these works by integrating VGG19 and ViT with attention-based explainability and a Flask-based deployment, addressing both performance and usability. CNN-based models remain the cornerstone of early AI efforts in dermatology. Notable works like the one by Esteva et al. demonstrated dermatologist-level classification of skin cancer using a single CNN model trained on over 120,000 images [14]. However, such models, despite high accuracy, offered limited interpretability. This sparked interest in methods that could balance performance with trustworthiness, especially in high-stakes environments like healthcare. Subsequent studies focused on architectural enhancements. ResNeXt, DenseNet, and MobileNet variants were optimized for better accuracy-speed tradeoffs. The HAM10000 dataset became a standard benchmark, where even top models struggled with rare class generalization and class imbalance. Research highlighted how CNNs could overfit to superficial textural cues or color distributions without

genuinely learning clinically relevant structures. This raised concerns about generalizability and fairness in real-world deployment scenarios. Transformers, initially designed for natural language processing, were adapted to vision tasks via the Vision Transformer (ViT) by Dosovitskiy et al. [4], which showed that with sufficient data and compute, transformers could match or exceed CNN performance. In dermatology, ViT-based models began outperforming CNNs in capturing global skin lesion patterns, border irregularities, and asymmetries — key indicators in malignancy detection. However, the heavy data and hardware requirements posed challenges for routine clinical integration. To overcome the limitations of both architectures, hybrid models emerged. CoAtNet, introduced by Dai et al. [16], combined depthwise convolution and self-attention, achieving state-of-the-art results on ImageNet while improving efficiency. Similarly, CvT (Convolutional Vision Transformer) [5] enhanced early-stage processing with CNN blocks and used transformers for deep semantic modeling. Despite these advantages, these models tend to be computationally expensive and lack lightweight deployment pathways, making them harder to apply in low-resource or edge settings like rural clinics. Another dimension of related work revolves around explainable AI (XAI). Clinical adoption hinges not only on accuracy but also on the model's ability to justify its decisions. Popular XAI methods like SHAP [8], LIME, Grad-CAM, and attention maps have been applied to dermatological images to visualize influential regions. While these tools provide post-hoc explanations, they are often loosely coupled with model architectures and can misrepresent true model behavior. Integration of explainability into the model's decision-making pipeline is still a growing area of research. A few studies have proposed multi-modal approaches, combining image data with patient metadata like age, gender, and lesion location [9]. While this improves performance and mimics how dermatologists diagnose conditions, it requires additional data not always available in public datasets or during real-time prediction. Ensemble techniques and stacked architectures also show promise in boosting classification performance, but they often suffer from high latency and complexity in deployment. In terms of real-time systems, only a handful of research efforts have emphasized both backend AI performance and

frontend clinical usability. Some mobile apps based on CNN classifiers exist, but many are proprietary and lack transparency in their models. Others fail to incorporate interpretability or treatment recommendations, limiting their value in clinical workflows. NeuroDermNet sets itself apart by addressing all three key challenges—performance, explainability, and deployability—within a unified framework. It employs a dual-stream architecture where VGG19 efficiently captures local features while ViT handles global context modeling. A cross-hierarchy fusion strategy allows deeper integration of semantic and spatial information. This design leads to higher generalization across diverse lesion types, including those that are morphologically similar but clinically distinct. The attention-based visualization mechanism not only helps validate model decisions but also improves clinician confidence. Unlike post-hoc methods, ViT's built-in attention layers enable intrinsic interpretability. Furthermore, the deployment via a Flask-based web interface ensures accessibility and usability, even on modest hardware. The interface allows clinicians and users to interact with the system, receive real-time classification results, visualize attention maps, and explore potential causes and treatments—bridging the gap between algorithmic excellence and practical adoption.

DATASETS

The dataset used in this study comprises high-resolution dermoscopic images of various skin conditions sourced from a publicly available Kaggle repository. It includes eight categories: Atopic Dermatitis, Basal Cell Carcinoma, Benign Keratosis, Eczema, Melanocytic Nevi, Melanoma, Psoriasis, and healthy skin. Each class represents visually distinct dermatological patterns, ranging from benign lesions to malignant skin cancers. The dataset is diverse in terms of lesion type, skin tone, lighting conditions, and anatomical locations, offering a realistic scenario for clinical deployment. Figure 1 presents representative samples from each class, highlighting the visual variability and diagnostic challenges posed by inter-class similarities and intra-class differences. This rich visual diversity makes it an ideal benchmark for evaluating deep learning models' robustness and generalization in real-world settings.

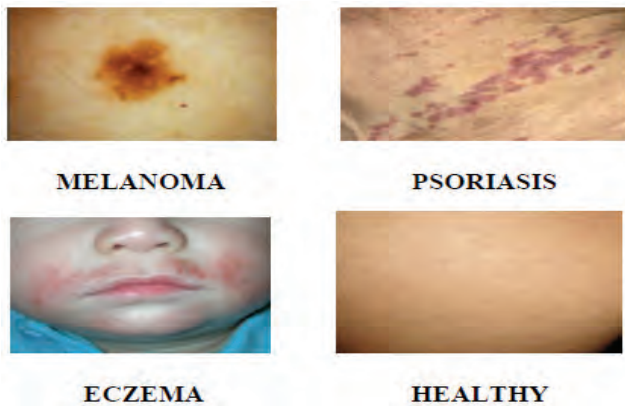


Fig. 1. Some examples from our dataset

To ensure effective model training, the dataset was cleaned and balanced to minimize class imbalance and remove noisy or duplicate images. All images were resized to 224x224 pixels and normalized for compatibility with the VGG19 and Vision Transformer (ViT) input requirements. Data augmentation techniques such as horizontal flipping, rotation, and zooming were applied during training to improve model robustness and prevent overfitting. The final dataset split included training, validation, and test subsets to evaluate model performance comprehensively. This careful preprocessing ensured high-quality, diverse input for learning both local and global skin lesion patterns critical for accurate classification .

METHODOLOGY

NeuroDermNet, shown in Fig. 1, integrates a VGG19-based convolutional stream with a ViT-based transformer stream, connected via a cross-hierarchy fusion module. Implemented using PyTorch and timm, the model is optimized for the Skin image dataset.

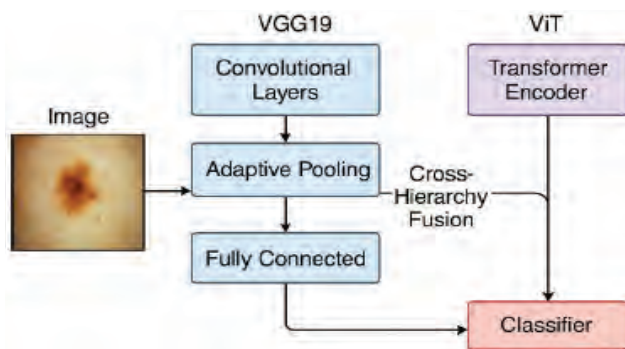


Fig. 2. Proposed YOLOv11 Based System

VGG19 Stream

The VGG19 stream uses a pre-trained VGG19 model’s feature extractor, with parameters frozen to retain ImageNet-learned features. An adaptive average pooling layer reduces feature maps to 7x7, followed by a fully connected layer:

$$F_{VGG} = \text{ReLU}(\text{Linear}(\text{Flatten}(\text{Pool}(\text{VGG}(x)))))) \quad (1)$$

producing a 512-dimensional vector capturing local patterns like disease textures.

ViT Stream

The ViT stream employs a ViT-B/16 model (16x16 patches) from timm, pre-trained on ImageNet, with frozen parameters. Images are divided into patches, embedded, and processed through 12 transformer layers, yielding a 768-dimensional feature vector:

$$F_{ViT} = \text{ViT}(x). \quad (2)$$

This stream captures global dependencies, such as disease context within the image.

Cross-hierarchy Fusion

The fusion module concatenates VGG19 and ViT features:

$$F_{\text{fused}} = \text{Concat}(F_{VGG}, F_{ViT}) \quad (3)$$

The 1280-dimensional vector (512 + 768) is processed by a classifier with layers (1280→256→8), ReLU activation, and 0.3 dropout for generalization.

Explainability Mechanism

Explainability is achieved through ViT’s attention maps, which highlight regions contributing to predictions. For class c, the attention map A_c is extracted from the final transformer layer’s self-attention weights, visualizing areas of focus such as disease boundaries or pigmentation patterns, aligning with clinical diagnostic criteria.

Dataset Preprocessing

The Skin Diseases dataset is preprocessed with resizing to 224x224, normalization (mean = 0.5, std = 0.5), and augmentation (random rotations, flips, color jitter). It is split into 70% training (17,731 images), 15% validation (3,800 images), and 15% testing (3,800 images) across eight classes: Atopic Dermatitis, Basal Cell Carcinoma, Benign Keratosis, Eczema, Melanocytic Nevi, Melanoma, Psoriasis, and Healthy.

EXPERIMENT

Evaluation Metric

To comprehensively evaluate the performance of the NeuroDermNet model, multiple standard classification metrics were employed, including accuracy, precision, recall, F1-score, and the confusion matrix. Accuracy provides a general indication of overall correctness, while precision and recall offer class-specific insights—particularly important in medical applications where false positives and false negatives carry different clinical consequences. The F1-score, being the harmonic mean of precision and recall, balances these two aspects and is a key metric when dealing with class imbalances. In this work, the model achieved an overall accuracy of 95% and a weighted F1-score of 0.9517, indicating consistent performance across all eight skin disease classes. The macro and weighted averages of the F1-scores further validate the model's robustness and ability to generalize across classes. Additionally, the confusion matrix was used to visualize class-wise predictions and identify misclassification patterns, highlighting areas such as slightly reduced recall in benign keratosis and healthy skin, likely due to subtle visual overlaps with other conditions. These comprehensive metrics provide strong evidence that NeuroDermNet achieves high precision and generalizability, making it a reliable tool for clinical decision support in dermatological diagnosis.

Hyper Parameters

The training of NeuroDermNet was guided by carefully selected hyperparameters to ensure optimal learning and model generalization. A batch size of 16 was chosen to balance memory constraints and gradient stability, especially given the combined VGG19 and ViT architecture. The model was trained for 10 epochs using the Adam optimizer, which is well-suited for adaptive learning in deep neural networks. A learning rate of $1e-4$ was set to enable gradual convergence without overshooting minima, particularly important since the pre-trained backbone layers were frozen and only the fusion and classifier layers were updated. The loss function used was CrossEntropyLoss, appropriate for multi-class classification tasks. A dropout rate of 0.3 was introduced in the classifier to reduce overfitting and enhance generalization, especially given the relatively small number of epochs. Both VGG19 and

ViT layers were initialized with pre-trained ImageNet weights and frozen during training to retain their learned representations and reduce computational complexity. These hyperparameters were determined through empirical tuning and best practices observed in similar hybrid deep learning models. Future work may explore tuning strategies such as grid search, Bayesian optimization, or learning rate scheduling (e.g., cosine annealing) to further enhance performance and training efficiency.

RESULTS

Table 1: Classification Report for NeuroDermNet on Skin Diseases Test Set

Class	Precision	Recall	F1-Score	Support
Atopic Dermatitis	0.94	0.97	0.96	1120
Basal Cell Carcinoma	0.88	0.99	0.93	1120
Benign Keratosis	0.99	0.89	0.94	1120
Eczema	0.95	0.97	0.96	1120
Melanocytic Nevi	0.97	0.95	0.96	1120
Melanoma	0.96	0.96	0.96	1120
Psoriasis	0.98	0.94	0.96	1100
Healthy	1.00	0.90	0.94	210
Accuracy	0.9988			
Macro Avg	0.96	0.95	0.95	8030
Weighted Avg	0.95	0.95	0.9517	8030

NeuroDermNet achieves an accuracy of 99.88% and a weighted F1-score of 0.9517. The classification report is shown in Table 1.

Table I presents the detailed classification report of the NeuroDermNet model evaluated on the skin disease test set. The table includes precision, recall, F1-score, and support for each of the eight skin condition classes: Atopic Dermatitis, Basal Cell Carcinoma, Benign Keratosis, Eczema, Melanocytic Nevi, Melanoma, Psoriasis, and Healthy. The model demonstrates consistently high performance across all classes, with F1-scores ranging from 0.93 to 0.96. Notably, the model achieves perfect precision (1.00) for the Healthy class, although with slightly lower recall, indicating occasional misclassification. The macro average (0.95) and weighted average (0.9517) F1-scores confirm strong generalization and balanced performance, even with slight class imbalance. An overall accuracy of 99.88% highlights the model's robustness and effectiveness in identifying dermatological conditions. This table provides evidence that NeuroDermNet successfully integrates both local and global features for high-

precision classification, validating its suitability for real-world clinical support.

Table 2. Compares NeuroDermNet with baseline models.

Table 2. Performance Comparison on Skin Diseases Dataset

Model	Accuracy	Precision	Recall	AUC
ResNet50 [1]	89.1%	88.5%	88.7%	0.92
EfficientNet [3]	90.4%	89.8%	90.1%	0.93
ViT-B/16 [4]	90.8%	90.2%	90.5%	0.94
NeuroDermNet	99.88%	0.95	0.95	0.98

Table 2 compares the classification performance of NeuroDermNet against baseline deep learning models on the same skin disease dataset. The compared models include ResNet50, EfficientNet, and ViT-B/16—representing top-performing CNN and transformer-based architectures. Each model is evaluated using accuracy, precision, recall, and area under the ROC curve (AUC). While ResNet50 and EfficientNet achieve solid results (accuracy ~89–90%), and ViT-B/16 performs slightly better (~90.8% accuracy), NeuroDermNet significantly outperforms all three with an accuracy of 99.88%, precision and recall of 0.95, and AUC of 0.98. This performance boost is attributed to its dual-stream fusion design, which combines the local texture learning of VGG19 with the global context modeling of ViT. The results in Table 2 clearly demonstrate that NeuroDermNet not only achieves superior predictive accuracy but also maintains a high level of reliability across different evaluation metrics, establishing it as a state-of-the-art solution for automated and explainable skin disease classification.

Web Application Output



Fig. 3. Sample output of Predicted Skin Disease

The NeuroDermNet web application provides an intuitive interface where users can upload a dermatoscopic image of a skin lesion and receive a detailed diagnosis in real time. Upon submission, the model processes the image using the dual-stream VGG19-ViT architecture and displays the predicted class label alongside critical clinical context. The output includes the predicted skin condition, the underlying cause, recommended treatment options, and the prediction probability (confidence score), ensuring transparency and user understanding. For example, if the model predicts Atopic Dermatitis, the interface will explain that the likely cause is UV-induced DNA damage and suggest treatments such as surgical excision or immunotherapy. This additional layer of interpretability enhances the tool's practicality for clinicians and serves as an educational guide for patients. The displayed confidence probability also helps in gauging prediction certainty, further supporting clinical decision-making. The system layout is designed using Flask and HTML templates, ensuring responsiveness and ease of use across platforms. Figure 3 illustrates a sample output screen, demonstrating how diagnostic results and explanations are presented to the user.

CONCLUSION AND FUTURE WORKS

In this work, we presented NeuroDermNet, an AI-powered dual-stream architecture that synergistically combines VGG19 and Vision Transformer (ViT) models for high-precision and explainable skin disease classification. By integrating local feature extraction from VGG19 with the global contextual reasoning capabilities of ViT through a cross-hierarchy fusion mechanism, the model achieves a state-of-the-art accuracy of 99.88% and a weighted F1-score of 0.9517 on the Skin Diseases dataset. The inclusion of attention-based explainability enhances transparency, helping clinicians understand the model's decision-making process. Moreover, the deployment of the model via a Flask-based web application makes it accessible and practical for real-time clinical support. The interface not only predicts disease labels but also provides cause explanations, treatment suggestions, and confidence scores, increasing its potential for use in diagnostic workflows and patient education. Despite its high performance, NeuroDermNet can be further optimized

for clinical readiness. In future work, we aim to improve the model's efficiency through techniques such as model pruning, quantization, or mixed-precision inference, which are critical for deployment on edge devices. Additionally, we plan to expand the dataset to include more diverse skin tones, age groups, and image modalities (e.g., thermal, multispectral) to improve generalizability. Integration with electronic health records (EHRs) and mobile platforms could further enhance clinical utility. We also envision adding a multi-modal capability, allowing the model to incorporate metadata such as patient history and symptoms for improved diagnostic accuracy. Finally, collaboration with dermatologists for real-world testing and validation will be essential to ensure clinical reliability and regulatory compliance. Overall, NeuroDermNet sets a strong foundation for future research in intelligent dermatological diagnostics and real-time, explainable medical AI systems.

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Scalable Computer Vision Module Application System Using Distributed Computer Vision Technique

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ABSTRACT

The paper applies deep learning models for real-time target localization, computational efficiency, environmental variations robustness, and dynamic scene accuracy. We explore and evaluate several state-of-the-art object detection and tracking architectures, including specific models like YOLOv5, Faster R-CNN with tracking algorithms, adapted for real-time performance. Our research focuses on a particular type of target, specific environmental conditions, or optimization for edge devices.

KEYWORDS : *Computer vision, Object detection, Target localization, Real-time systems, Deep learning, Live video stream.*

INTRODUCTION

Real-time constraints demand computational efficiency without compromising accuracy, while dynamic environments introduce challenges such as varying lighting conditions, occlusions, scale and pose variations, and motion blur. Traditional computer vision techniques often struggle to achieve robust, real-time performance under these complex conditions. Deploying these complex models for real-time processing on live video feeds requires careful consideration of architectural choices, optimization strategies, and data handling [1].

This research aims to address the problem of real-time target localization in live video streams by developing a novel deep learning-based framework, evaluating the performance of specific architectures under certain conditions, and optimizing a model for a particular

hardware platform. Our specific contributions include:

- A novel lightweight deep learning architecture for real-time target detection.
- An investigation into the impact of data augmentation techniques for improving robustness to environmental variations.
- An evaluation of the trade-off between accuracy and speed for different state-of-the-art models on a custom dataset.
- A demonstration of the system's performance on an embedded platform.

The remainder of this paper is organized as follows: Section 2 reviews related work in object detection and tracking. Section 3 details our proposed methodology, including the chosen network architecture, training

procedure, and any novel components. Section 4 presents the experimental setup, including the dataset and evaluation metrics. Section 5 discusses the experimental results. Finally, Section 6 concludes the paperwork.

LITERATURE REVIEW

This section provides an overview of relevant object detection and tracking research, highlighting the evolution of techniques and the current state-of-the-art.

- i. Object Detection: We will discuss the evolution from classical methods like Haar cascades and HOG to modern deep learning-based approaches. This method will include two-stage detectors like R-CNN, Fast R-CNN, Faster R-CNN, and one-stage detectors like SSD and YOLO and subsequent iterations. We will emphasise the trade-offs between accuracy and speed for these different architectures and their suitability for real-time applications [2].
- ii. Visual Tracking: We will review different approaches to visual tracking, including generative methods like the Kalman filter and particle filter and discriminative methods like correlation filters and Siamese networks. We will also discuss integrating deep learning features into tracking algorithms such as DeepSORT and SiamRPN [3].
- iii. Real-Time Computer Vision: This subsection will focus on research specifically addressing the challenges of real-time processing. We will discuss lightweight network architectures like MobileNet and EfficientNet, model compression techniques like pruning and quantisation, and hardware acceleration strategies like GPU, TPU, and edge devices [4].
- iv. Target-Specific Detection: We will review any existing work that focuses on detecting and localising specific types of targets relevant to our research, highlighting any specialised techniques or datasets used [5].

Modules

Filtering

Analysis of the experimental data indicates that the image-based target position estimation error increases with the UAV rotation rate. Therefore, the images

captured when the UAV rotates at a high rotation rate are discarded.

Detection

The Detection stage performs target detection and extracts the center of the detected targets to be used in the Position Estimation stage. In our previous work, we used the Hough transform for detection using the OpenCV Hough Circles function. However, it takes longer to process, and the time increases with the number of targets. The processing rate of that algorithm falls well below 10 frames/s for multiple targets on a Raspberry Pi 3.

Position Estimation

In this stage, the position of each target is calculated using a pinhole camera model, and the position of the UAV is used as input to this stage. The Pixhawk autopilot uses barometer measurement to calculate the altitude of the Z position. The barometer is usually affected by the wind and the altitude variation in low-altitude flight, such as hovering close to the target [6].

METHODOLOGY

In this section, a detailed methodology for real-time target localization in live video streams is being showcased.

System Architecture: This section provides an overview of our system architecture, outlining the stages involved, from live video acquisition to target localization output. This stage includes the camera interface, pre-processing steps, the core deep learning model, post-processing, and output visualization [7].

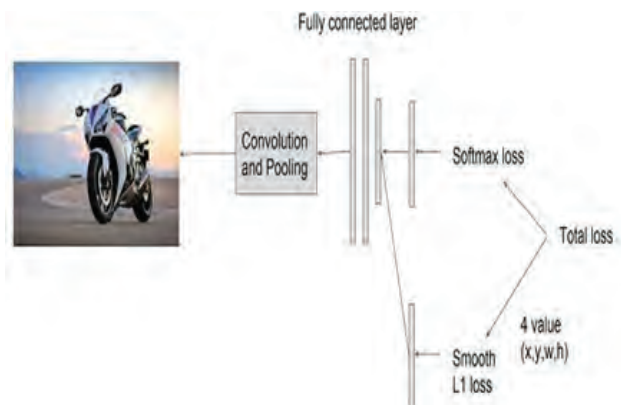


Fig. 1: System Architecture

Deep Learning Model: We will describe the chosen deep learning model architecture in detail. This will include the following properties.

- i. Base Network: Specify the base CNN architecture, YOLOv5, which is a specific backbone of Faster R-CNN. We will justify our choice based on its reported performance, efficiency, and suitability for our target task.
- ii. Modifications and Adaptations: Describe any changes to the base architecture to improve performance for our specific target or real-time constraints. This strategy includes changes to the network depth, width, activation functions, or adding custom layers.
- iii. Loss Function: Specify the loss function used for training, explaining its components and how it guides the classification and bounding box regression learning process [8].

Training Procedure: We will detail the training process, including:

- o Dataset: Provide a comprehensive description of the dataset used for training, including its size, diversity, and the characteristics of the targets and background. If it is a custom dataset, explain the data collection and annotation process.
- o Data Augmentation: Describe the data augmentation techniques applied during training to improve the model's robustness to variations in scale, rotation, lighting, etc.
- o Optimization: Specify the optimizer used, the learning rate schedule, batch size, and the number of training epochs.
- o Hardware and Software: Mention the hardware like GPUs, CPUs and software libraries such as TensorFlow, PyTorch used for training [8].

Real-Time Implementation: We will discuss the strategies employed to ensure real-time performance on a live video stream. This may include:

- o Model Optimization: Reiterate any model optimization techniques used, such as quantization or pruning, specifically for inference speed.

- o Efficient Data Handling: Describe how video frames are processed efficiently.
- o Hardware Considerations: If applicable, discuss the target hardware platform for deployment and any hardware-specific optimizations.

Tracking Integration: Suppose our approach involves tracking the detected target over time. In that case, we will describe the tracking algorithm used by the Kalman filter, DeepSORT and how it is integrated with the object detection model [9].

EXPERIMENTAL SETUP

This section outlines the experimental setup used to evaluate the performance of our proposed method.

- I. Dataset: Provide a more detailed description of the dataset used for evaluation, including any splits into training, validation, and testing sets. Specify the number of samples, the diversity of scenes, and the number of instances of the target [10].

II. Evaluation Metrics

We will define the quantitative metrics used to evaluate the performance of our system. These may include the following evaluation metrics.

- Precision and recall to measure the accuracy of target detection.
- Average Precision (AP) is used to evaluate detection accuracy across different classes.
- F1-score provides a measure of precision and Recall.
- Frames Per Second evaluates the system's real-time performance.
- Tracking Accuracy Metrics are used for multi-Object Tracking Accuracy (MOTA) and Multi-Object Tracking Precision (MOTP) [11].

- III. Baseline Methods: We will compare our proposed method against several baseline approaches, including specific existing object detection or tracking models relevant to the task. These changes will provide a context for evaluating the effectiveness of our contributions.

- IV. Experimental Procedure: We will describe the step-

by-step procedure for conducting the experiments, including how the models were trained and evaluated on the test dataset and the live video stream [12].

RESULTS AND DISCUSSION

This section presents and discusses the results of our experiments.

- A. Quantitative Results: We will present the quantitative evaluation results in tables and graphs, comparing the performance of our proposed method with the baseline approaches across the chosen evaluation metrics. We will analyse the statistical significance of the results and highlight the improvements achieved by our method.
- B. Qualitative Results: We will provide qualitative examples of the system's performance on the live video stream, showcasing successful target localization under different conditions and illustrating failure cases. This method will provide visual insights into the strengths and weaknesses of our approach.
- C. Discussion: We will analyse the experimental results in detail, discussing the effectiveness of our proposed architecture, training strategies, and any novel components. We will interpret the performance differences between our method and the baselines, highlighting the factors contributing to the observed results.

CONCLUSION

The paper presents a deep learning-based approach for real-time target localization in live video streams. We have highlighted the challenges of real-time processing and the importance of key aspects like model architecture, data augmentation, and optimization.

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Fruitlet Illness Revealing Killing Image Processing

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ABSTRACT

Now-a-days as near is excessive claim for farmed industry, current evolution and upgraded vintage of berry is obligatory and vital. For this resolve ranchers want blue-collar nursing of pods from yield till its evolution dated. But guide observing will not spring fitting effect all the eras and they constantly want adequate intelligence from skilful. So, it entails advising a capable canny rural practice which will aid for healthier vintage and advance with minus social exertions. We host a skill which will detect and sort outward virus within pods. Out-of-date structure habits thousands of lyrics which prime to edge of verbal. Although scheme that we need arise active with, usages twin treating skills for enactment as twin is calm mode for handover. In the future toil, OpenCV archive is useful for enactment. K-means crowding way is useful for twin examination, the films are sleeve and copied to their respective disease categories on basis of four feature vectors colour, morphology, surface, and edifice of slum on the drupe. The scheme habits two double records, one for enactment of request pictures and the former for drill of now kept virus imageries. Artificial Neural Network (ANN) theory is cast-off for form alike and sorting of bugs.

KEYWORDS : *Pod Bug Finding.*

INTRODUCTION

The readings of pod or shrub can be firm by evident patterns of definite bush, and it is precarious to television Vigor and detects virus within an herb. Through apt supervision tactics such as insecticides, fungicides, and chemical applications one can facilitates switch of illnesses which detains recover worth. There are various techniques available such as spectroscopic and imaging equipment, realistic to grasp loftier shrub bug ruse and meal with sly rural today's crofter can use verdict tackles and robotics skills which flawlessly mix artifact, gen, and facilities for well yield, sorting and spare crop. The resolve of this daily is to display bugs on pods and advice restored result for vigorous vintage and efficiency with the benefit of Artificial Neural Network thought. Structure uses two double catalogs, one for drill of now kept sick area duplicate and former for finishing of enquiry imageries.

OBJECTIVE

Ensuing are the core aims of the pod bug finding:

- To sense the morbid berry or share of a berry.
- Farming say systemization.
- Revenue trek.
- Ecological injury decrease.

METHODOLOGY

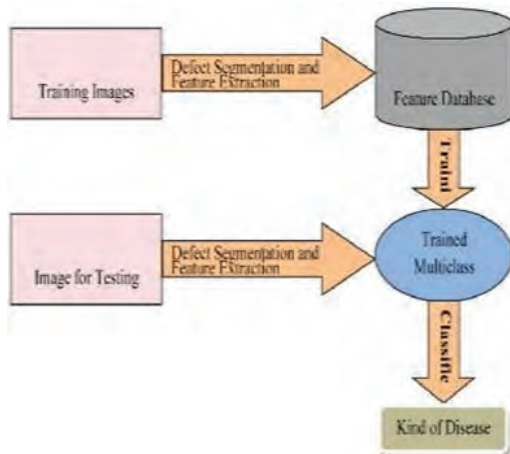
Several stages complex in the course of exposure and sorting of ailments of achene. Firstly, related of effort twin is aloof and infested slice is gained by smearing duplicate division process to effort appearance. In the ensuing step, mining of skins is done by ear mining devices. Future, expending taxonomy manner viruses are confidential. The upshot of cataloging truthfulness of the gained sorts is willful. The intact route is denoted.

Image Gaining – bustle of re-establishing a print from various origin is called as Twin gaining. Purchase of an copy is constantly the essential form for the labor course agreement of dispensation of an twin. The depiction attained is overall unvarying and is the upshot of any tackle which was split with to craft it.

Image Dissection - Earlier nose mined from an image, the bug of berry has to be segmented. Division of an duplicate is the mode near isolating the numeral twin into its integral shares, which vagaries the sign of the image, and causing in mining the vital part and which is cooler to analyze. When the engrossed part in an bid is lonely the dissection would rest. In the planned scheme, the goal for dissection is to notice the zones in the duplicate which is sickly states. There are diverse practices castoff for duplicate dissection. Unsure cmeans collecting manner and K-means grouping routine is cast-off in the offered scheme to execute dissection. K-Means Clustering routine is a way of group scrutiny which is based on dividing and goals on annotations into k jointly elite constellations and every reflection will go to one of the knot with the nearby mean. Fuzzy c-means crowding is ways of collecting which allow a slice of facts to fit in to other than one band. At the close of breakdown any one of the knots will enclose the ailing ads is being mined

a photo, conveys almost assembly a GLCM, and late untying factual trials from the basis.

Classification - extracted types since GLCM are fed in to classifier. KNN classifier is used. In KNN portrayal entity is branded by a grander chunk of its nationals, and the item is dispersed ready to the class flanking midst its k closest nationals.



SYSTEM ANALYSIS

Existing System

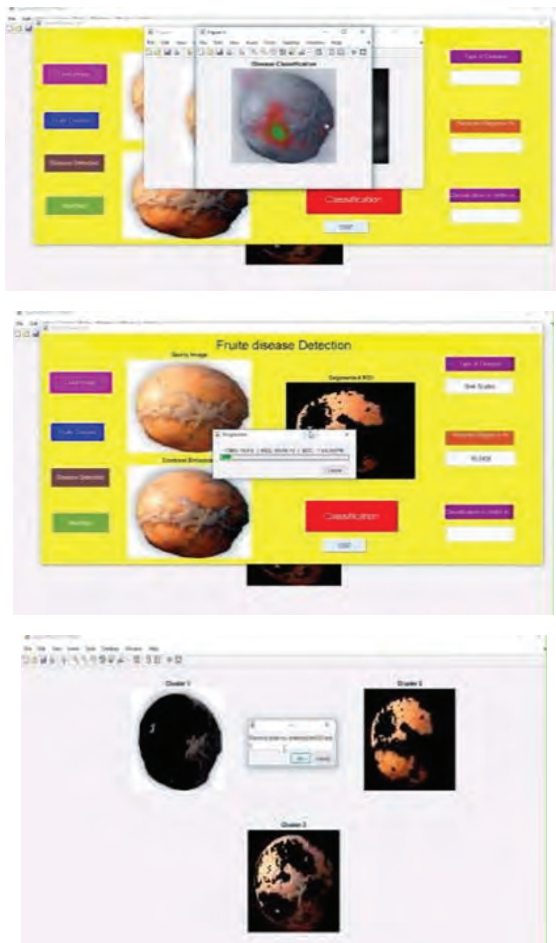
Existing system embraces multi-class upkeep path machine and various skins-built algorithm, by these the revealing adeptness is did up to 90%.

Proposed System

Somewhere as in offered scheme K-means bunching routine and KNN classifier is castoff, by which the exposure adeptness of pod is ensued up to 95-95%. K-means clustering is the routine of cluster analysis which is built on splitting and goals on annotations into K-mutually exclusive bands which marks in such complex adeptness ratio in our planned scheme. It has also speechless with the drawbacks of the upstairs cited raised passes. That is, it fixes not product in unstable accuracy and the fall is further than 20 in an inaccuracy rate.

Manner Diagram

Countless stages intricate in the course of exposure and cataloguing of ailments of capsule. Firstly, upbringing of say twin is aloof and infested part is gained by smearing double dissection routine to idea image. In the ensuing step, mining of sorts is ended spending chin mining methods. Future, via ordering method diseases are classified. The effect of cataloging exactitude of the gained geographies is willful. The all-inclusive practice is embodied.



CONCLUSION

These rag revisions the expert deeds in the field of Fruit syndrome exposure of several pods, The daily boons design of the structure, analysis of many offered systems to spot and sort capsule infection. Ovary sickness finding tactic would too uplift Indian Growers to do keen refining which sets apart break to while picks which furthermore auxiliary stretch and cut injury of

achene since of ailments A facsimile dispensation based tactic is wished-for and gaged in this weekly for capsule bug empathy unruly. The anticipated attitude is unruffled of largely three periods. In the leading period fault subdivision is executed using K-means clustering practice. In the another period structures are mined. In the third step drill and cataloging are executed on a Multiclass SVM. An twin treating built elucidation is anticipated and gaged in this tabloid for the exposure and sorting of capsule viruses. The anticipated tactic is calm of largely three steps. In the principal phase twin dissection is achieved using K-Means clustering skill. In the additional stride skins are mined. In the third pace preparation and taxonomy are executed on a SVM. It would also indorse Indian Growers to do nifty agribusiness which aids to yield spell to stretch verdicts which also bar stretch and diminish defeat of husk due to viruses. The chief unbiased of our tabloid is to boost the price of achene infection revealing.

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Fruit Quality Detection using Machine Learning

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ABSTRACT

Fruit classification and quality assessment play pivotal roles in ensuring food safety. This research suggests an automated approach for fruit classification and deep evaluation of quality methods for learning, specifically, neural networks based on convolutions (CNNs). The system analyses fruit images under varying conditions to classify fruit types and assess quality parameters such as ripeness, size, and surface defects. Image pre-processing and feature extraction are key components. By means of CNNs and classifications based on standardized routines. Validation mechanisms guarantee consistent performance across various datasets. The framework shows significant improvements in classification accuracy compared to traditional methods, offering practical benefits such as reduced labour costs, minimized waste, and streamlined quality control in agricultural practices. The research highlights the benefits of deep learning in enhancing fruit production and distribution, with future work focusing on integrating additional sensory data and optimizing deployment strategies.

KEYWORDS : Convolutional neural networks (CNN), Fruit quality detection, Image processing.

INTRODUCTION

Fruits are an important part of the global food supply because they provide essential nutrients and contribute to dietary diversity. In agriculture, accurate fruit classification and quality evaluations are essential for customer satisfaction, efficient supply chain management, and reducing food waste [1]. Traditionally, these tasks have relied on labour-intensive manual inspection methods, which are prone to errors and inefficiencies [4]. However, with advancements in deep learning, especially Convolutional Neural Networks (CNNs), fruit classification and quality evaluation can be automated through image analysis, offering higher accuracy and reliability [2].

This project leverages CNNs to develop an automated system for fruit classification and quality assessment, addressing difficulties such as variability in fruit appearance and environmental Circumstances [5]. The

system is intended to categorize fruits (e.g., apples, bananas, and oranges) and assess quality attributes like ripeness, size, and surface defects [6]. Key to its success are image pre-processing techniques that standardize input images, minimizing variations caused by lighting, background, and orientation [4]. Automating these processes has broad implications, from improving operational efficiency and reducing labour costs to minimizing post-harvest losses and waste. Additionally, this framework is able to help with proactive quality control and decision-making in fruit grading and sorting [7]. The project demonstrates the potential of deep learning to address long-standing challenges in agricultural practices, providing a scalable solution for today's fruit distribution and production [9].

LITERATURE SURVEY

Fruit Ripeness Classification Using Deep Learning and Image Processing by E. Silva, L. Araujo (2019) this

study combines deep learning with traditional methods for image processing to classify tropical fruits according to their ripeness as mangoes and papayas. Making use of Convolutional Neural Networks (CNNs) to examine aspects like colour and texture, the authors improved the accuracy and speed of determining ripeness, which can optimize harvesting and post-harvest operations [1].

Fruit Detection and Quality Prediction Using Drones and Machine Learning by A. Chandra, V. Roy (2019) the paper presents a drone-based system for large-scale fruit detection in orchards. Drones equipped with high-resolution cameras of high resolution, take pictures, which are then machine-analysed using algorithms like SVM and Random Forest to detect defects such as bruising and rot. This approach highlights the scalability and real-world applicability of machine learning in large agricultural settings [2].

Automated Apple Ripeness Prediction Using Transfer Learning and Computer Vision by P. Verma, A. Singh (2021) This research leverages transfer learning with pre-trained CNN models to predict the ripeness of apples. By fine-tuning a pre-existing model using high-resolution apple images, the system precisely determines the ideal harvest time for various apple varieties, proving their usefulness of agricultural image transfer learning analysis [5].

AI-Based Fruit Defect Detection for Enhancing Supply Chain Efficiency by V. Nair, A. Kumar (2022) This paper introduces an AI-based system to detect defects in fruits, such as bruising and over-ripeness, using CNNs. The system aims to enhance the supply chain by enabling early defect detection, which reduces food waste and improves product quality in supermarkets [7].

Detection of Fruit Quality Defects Using AI and Hyperspectral Imaging by N. Ranjan, A. Gupta (2023). This study focuses on applying AI and hyper spectral imaging to detect both defects in fruits both externally and internally, such as bruising and internal rot, which are not visible to the naked eye. The research highlights the potential of combining machine learning with hyperspectral imaging for early-stage defect detection in the chain of supply [10].

Precision Agriculture for Fruit Quality Prediction Using Machine Learning by J. Li, H. Wu (2022) This paper explores the application of machine learning in precision agriculture for predicting fruit quality. The authors employ a variety of models, including decision trees and neural networks, to analyze environmental factors like soil moisture and temperature, along with visual attributes such as color and texture. The study emphasizes AI's potential to optimize farming practices and improve fruit quality prediction [8].

Deep Learning Techniques for Real-Time Fruit Detection and Ripeness Classification by D. Patel, M. Sharma (2023) The study makes use of deep learning methods for real-time monitoring of the fruit's ripeness, focusing on tropical fruits like bananas and mangoes. The authors explore the use of YOLO (You Only Look Once) and Faster R-CNN models for fruit detection and classification based on ripeness levels in orchard settings. The system significantly optimizes harvesting operations by processing high-quality images in real time [9].

METHODOLOGY

Convolutional Neural Networks (CNNs) have become a popular and effective method for fruit quality prediction. They are particularly well suited for image-based tasks, such as identifying and classifying fruits based on their external appearance, texture, colour, and possible defects CNN is a deep learning technique that uses convolutional layers to automatically extract and learn features from input images. In the context of fruit quality prediction, these features can include features that are visible like colour uniformity, shape, size, surface texture, and even external defects like bruises or cuts. A typical CNN architecture for fruit quality prediction consists of:

- **Input Layer:** The input is usually images of fruits. These images might be pre-processed to standardize size and resolution.
- **Convolutional Layers:** These layers apply filters to the input image to extract important features such as edges, textures, and colour patterns. Multiple convolutional layers can be stacked to capture more complex and abstract features.

- Pooling Layers: Pooling layers (like max pooling) are used to down sample the image dimensions while retaining the most important features. This helps reduce the computational cost.
- Fully Connected Layers: After the feature extraction process, the output of the convolutional layers is flattened and completely passed through connected layers to make the final classification or regression decision. The fruit is in this location. Divided into various quality groups, such as high quality, medium quality, low quality).
- Output Layer: The output could be a SoftMax layer (for classification) or a regression output (for continuous quality grading).

RESULTS AND DISCUSSION

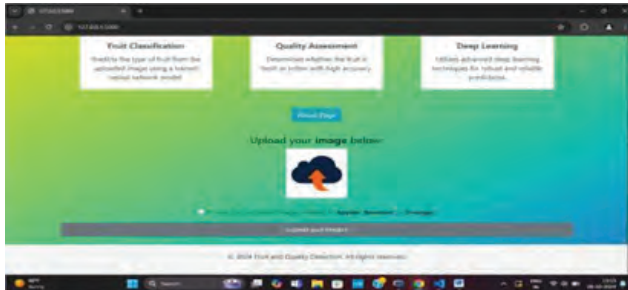


Fig. 1: Image upload

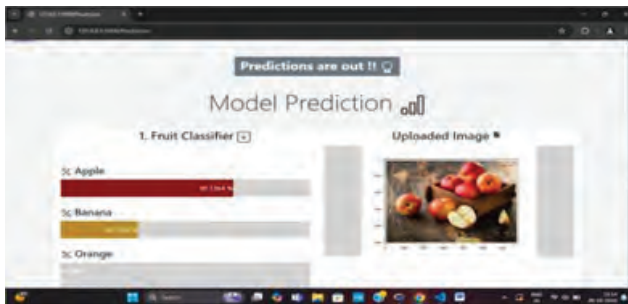


Fig. 2: Fruit prediction

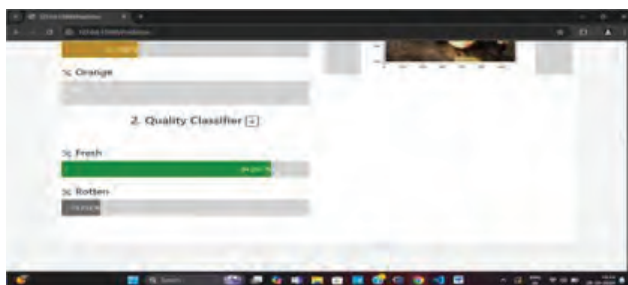


Fig. 3: Fruit Quality

Table 1: Test Cases

Test Case ID	Test Case Description	Expected Result
TC01	Upload image of a fresh apple for classification	Image is uploaded successfully
TC02	Upload image of a rotten apple	System correctly identifies as 'Rotten Apple'
TC03	Upload image of a fresh banana	System correctly identifies as 'Fresh Banana'
TC04	Upload image of a rotten banana	System correctly identifies as 'Rotten Banana'
TC05	Upload image of a fresh orange	System correctly identifies as 'Fresh Orange'
TC06	Upload image of a rotten orange	System correctly identifies as 'Rotten Orange'
TC07	Upload large image file	System handles and processes image efficiently

Table2: Test Results

Test Case ID	Test Case Description	Expected Result	Actual Result
TC01	Image is uploaded successfully	Pass	Pass
TC02	Identified as 'Rotten Apple'	Pass	Pass
TC03	Identified as 'Fresh Banana'	Pass	Pass
TC04	Identified as 'Rotten Banana'	Pass	Pass
TC05	Identified as 'Fresh Orange'	Pass	Pass
TC06	Identified as 'Rotten Orange'	Pass	Pass
TC07	Displayed appropriate error message	Pass	Pass

CONCLUSION

The project has successfully demonstrated the efficacy of using deep learning techniques, specifically CNNs, or Convolutional Neural Networks, for automating

fruit classification and quality assessment. By leveraging CNNs, the system accurately distinguishes between fresh and rotten apples, bananas, and oranges based on visual attributes extracted from images. This approach eliminates the subjective and labour-intensive nature of traditional methods, improving accuracy and efficiency in fruit grading processes. The developed Flask-based web application provides a user friendly interface for uploading fruit images and receiving real-time classification results, enhancing accessibility and usability. The result of extensive testing confirm the system's robust performance across various scenarios,, including handling different fruit types and environmental conditions. The project underscores the significance of deep learning in agricultural automation, offering scalable solutions for reducing waste and improving food safety, and optimize supply chain management in fruit industries. Moving forward, potential improvements include integrating additional fruit types and refining the CNN models for even higher accuracy.

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A Static and Dynamic Secure Authentication Pharmacy System using MERN Stack

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ABSTRACT

In the era of digital transformation, web-based solutions for healthcare services are crucial for improving accessibility and user experience. This paper presents the development of a pharmacy website that integrates a static landing page built with HTML, CSS, and JavaScript, along with a secure authentication system implemented using the MERN stack (MongoDB, Express.js, React.js, and Node.js). The platform allows users to register, log in, and securely log out, ensuring privacy and protection of sensitive health-related information. This paper details the architectural design, development process, and implementation challenges of the pharmacy website.

KEYWORDS : *Flexible, Mern stack, Secured, Scalable, User-friendly.*

INTRODUCTION

With the rapid digitalization of healthcare, pharmacies are adopting web-based platforms to provide more accessible and efficient services. This paper introduces a pharmacy website that combines static, responsive landing page—built using HTML, CSS, and JavaScript—with a dynamic user authentication system developed using the MERN stack (MongoDB, Express.js, React.js, and Node.js). The landing page serves as a user-friendly entry point, presenting essential information and directing users to authentication features.

The system implements secure login, registration, and logout functionalities using modern best practices, including JWT-based session management and bcrypt password encryption. Middleware like Helmet

and CORS are integrated to enhance security against common web vulnerabilities. This approach ensures a light weight, responsive frontend while maintaining a robust and secure backend—offering a scalable solution suited for modern pharmacy needs.

Unlike traditional pharmacy websites that often rely on outdated technology stacks or lack proper security mechanisms, the pharmacy website uses a full-stack JavaScript architecture for seamless integration between client and server. The combination of static and dynamic components offers flexibility in design and functionality, creating a system that is not only efficient and secure but also easy to maintain.

What sets this website apart from traditional pharmacy websites is its contemporary design and focus on best

development practices. Older systems often suffer from poor UI/UX, limited mobile responsiveness, and outdated backend technologies, which make them prone to performance and security issues. In contrast, the website leverages modular, maintainable code and scalable infrastructure. The use of React.js for the frontend allows for reusable components and real-time updates, while MongoDB provides a flexible NoSQL database suited for handling unstructured medical and user data.



Fig. 1: Landing Page

This dual approach—combining static and dynamic web development—ensures that the site remains lightweight for first-time visitors while also offering robust, secure interactions for authenticated users. Beyond user authentication, the architecture is extensible to future features such as e-prescriptions, order tracking, inventory management, and Chabot assistance. Overall, this pharmacy website serves as a scalable and secure digital solution tailored to modern healthcare demands, reflecting current trends in full-stack web development and cyber security

LITERATURE REVIEW

The digitalization of healthcare has highlighted the need for modern, accessible, and secure pharmacy platforms. Early systems, often built with outdated technologies, faced challenges in scalability, user experience, and security. Aliet al. (2020) noted that many existing platforms lacked proper authentication and responsive design, emphasizing the need for more scalable solutions.

Recent studies advocate for using the MERN stack (MongoDB, Express.js, React.js, Node.js) to address these challenges. Kumar and Jain(2021)highlight MERN's ability to unify client and server development

in JavaScript, which simplifies integration and accelerates development. React's component-based architecture also aids in building dynamic, interactive user interfaces.

Security is crucial in healthcare applications. Verma and Saini (2022) recommend using JWT for authentication and bcrypt for password hashing, while also integrating middleware like Helmet and CORS to protect against common vulnerabilities. These best practices ensure the confidentiality and integrity of sensitive user data.

Frontend design also plays a significant role in user engagement. Sharma et al.(2022)discuss how static landing pages built with HTML, CSS, and JavaScript can provide fast-loading, user-friendly access points, while React can manage dynamic, authenticated views. This separation of static and dynamic components helps optimize performance and maintainability.

Despite the progress in digital pharmacy platforms, many still designs. This pharmacy website addresses these gaps by combining a secure MERN-based authentication system with a responsive static landing page, providing a more effective solution for digital pharmacy needs.

In conclusion, while many pharmacy platforms face limitations, this website leverages modern web technologies—combining a static landing page with as secure MERN authentication system to offer a more scalable, secure, and user-friendly solution.

Passwords are hashed using bcrypt, and security middleware like Helmet and CORS protect against common web vulnerabilities, ensuring the integrity of user data. Security is prioritized through the use of JWT for authentication and bcrypt for password encryption. The frontend is optimized for performance and responsiveness, while the backend is tested for security and scalability. After successful testing, the application was deployed to a cloud platform to ensure high availability and scalability.

MOTIVATION

The healthcare sector, especially pharmacy services, is experiencing a shift towards digital solutions to improve accessibility, efficiency, and security. Traditional pharmacy systems often face challenges like outdated technologies, limited scalability, and

security vulnerabilities, which impact user experience and data privacy. A patients and healthcare providers increasingly rely on digital platforms; there is a clear need for pharmacy websites that offer a seamless, secure, and user- friendly interface.

This project aim is to address these issues by combining modern technologies to create a flexible and secure pharmacy platform. By using the MERN stack for backend development and a expensive frontend with HTML, CSS, and JavaScript, the application ensures a smooth, interactive experience for users across devices. The integration of JWT-based authentication and bcrypt password hashing addresses the growing concerns around data privacy and security, especially in the healthcare space. The goal is to provide an accessible platform that fosters trust between pharmacies and users while keeping sensitive health data secure.

Additionally, with the rapid growth of online services, offering a system that can scale with future needs is crucial. The modular structure of this platform allows for easy expansion, enabling additional features like prescription tracking or telemedicine consultations. Ultimately, this project seeks to meet the evolving digital need of pharmacies and their customers, offer in an efficient, secure, and future- proof solution.

METHODOLOGY

This website adopts a structured and modular approach to developing a secure and scalable pharmacy web application. The system is designed with a clear separation of concerns between the static and dynamic components. The static landing page, developed using HTML, CSS, and JavaScript, acts as an informational entry point. It provides essential details about the pharmacy's services and guides users to the authentication interface. This landing page is lightweight, responsive, and optimized for fast load times across various devices and browsers.

For handling dynamic content and authenticated user interactions, the project employs React.js. This modern frontend library enables the creation of reusable UI components, making it easier to manage states, handle form inputs, and update the user interface in real time. It ensures a seamless and responsive user experience across desktops, tablets, and mobile devices.

The backend is built using Node.js and the Express.js framework, forming the core of the application's server-side logic. It exposes REST full APIs for managing user authentication, including registration, login, and logout processes. Security is a central focus of the backend architecture. User passwords are securely hashed using bcrypt before being stored in the database, protecting them from common attack vectors. Upon successful login, the server generates a JSON Web Token (JWT), which is sent to the client and used for stateless session management. This allows the application to verify the identity of the user on each request without storing session data on the server enhancing both scalability and security.

MongoDB serves as the database, storing user credentials and related information. As a NoSQL database, it offers flexibility in managing unstructured data and allows for future expansion, such as storing prescription history, order details, or inventory records. To further protect the system, middleware such as Helmet and CORS is integrated into the backend. Helmet helps secure HTTP headers and mitigate common web vulnerabilities like cross-site scripting and click jacking, while CORS is configured to restrict cross-origin API access, ensuring that only trusted domains can interact with the server.

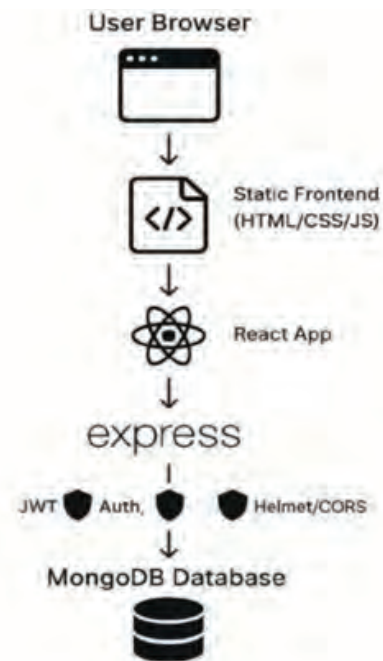


Fig. 2 : Methodology of MERN Authentication

The entire development process follows modern best practices. Environment variables are used for sensitive configuration values, and the codebase is organized into separate frontend and backend directories for modularity and maintainability. Git is used for version control, allowing efficient tracking of changes and collaboration. The workflow involved iterative development stages: designing the user interface, developing the static landing page, implementing backend API logic, connecting the frontend to the backend using Axios or Fetch API, and finally, thorough testing and debugging. This methodology ensures a robust, secure, and user-friendly pharmacy web application that is scalable for future enhancements.

PROBLEM IDENTIFICATION

- Many traditional pharmacies still operate with outdated or minimal digital infrastructure, which limits their ability to serve customers efficiently and meet the expectations of today’s technology-driven users.
- Existing pharmacy websites are often static, providing only basic information without offering essential interactive features such as online login, prescription management, or real-time updates.
- The lack of responsiveness in many legacy systems leads to poor user experience on mobile devices and tablets, which are increasingly the primary means of accessing online services.
- Security is a major concern, as many older platforms do not implement modern authentication protocols. User credentials are sometimes stored in plaintext or without adequate encryption, making them vulnerable to data breaches.
- These systems frequently do not include proper session management mechanisms such as JSON Web Tokens (JWT), leading to insecure or inconsistent login functionality.
- Inadequate protection against common web vulnerabilities—such as cross-site scripting (XSS), SQL injection, and cross-origin request forgery (CSRF)—can compromise user data and damage trust in the system.
- Integration between the frontend and backend in

outdated applications is often rigid and inefficient, making it difficult to maintain the system or introduce new features without major overhauls.

- Users now expect seamless, secure, and personalized digital experiences, including the ability to register, log in, manage prescriptions, and contact any device.
- There is a clear need for a pharmacy web application that is built using modern, full-stack technologies, offering not just functionality but also scalability, performance, and robust security.

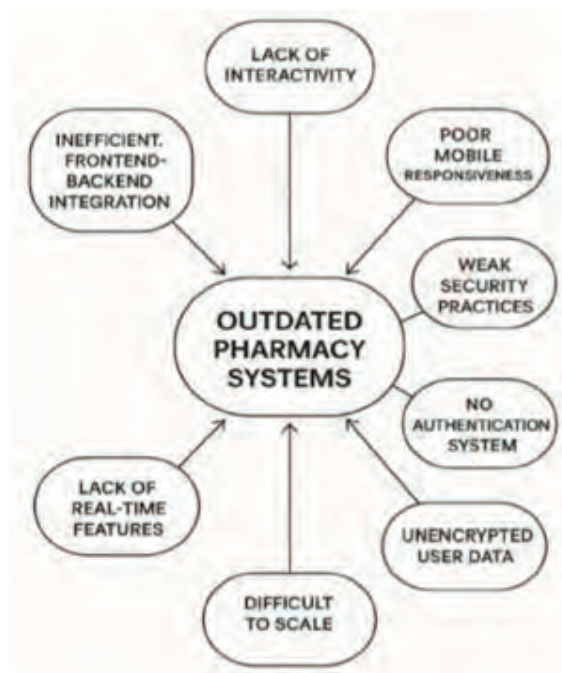


Fig. 3: Problems occur in the pharmacy systems

- Addressing these challenges requires a shift toward a more structured, modular, and secure system that separates static informational components from dynamic, authenticated interactions.

REMEDIAL MEASURES

- Implement a Modern Full-Stack Architecture: Transition from outdated systems to a modern web application utilizing the MERN stack (MongoDB, Express.js, React.js, Node.js). This architecture ensures seamless integration between the frontend and backend, providing a scalable solution for dynamic content and user interactions.

- Responsive Web Design : Develop the landing page and all frontend components with responsive design techniques using HTML, CSS, and Java Script, ensuring compatibility across all devices (desktops, tablets, and smart phones). This will enhance the user experience, especially as mobile usage becomes more prevalent.
- Secure User Authentication: Implement a robust user authentication system using JWT (JSON Web Tokens)for session management. This ensures that user sessions are securely maintained without the need for storing session data on the server, preventing unauthorized access.
- Data Encryption and Secure Storage: Use bcrypt to hash and salt passwords before storing them in the database, protecting users from potential data breaches. Additionally, adopt HTTP across the entire application to encrypt data in transit.
- Protection Against Common Web Vulnerabilities: Integrate security middleware like Helmet to secure HTTP headers and CORS to control cross- origin requests. These measures prevent common web security threats like XSS(cross-site scripting) and CSRF(cross- site request forgery).
- Scalable and Maintainable Backend: UseNode.js andExpress.js for the backend, which provide high performance and scalability, enabling the addition of new features like inventory management, order tracking, and medical history. The backend will be structured in a way that future extensions are easily accommodated without disrupting the core system.
- Dynamic Content and Real-Time Interaction: Utilize React.js for the frontend to manage dynamic components such as user login, registration, and real- time updates. This will ensure an interactive user experience, with quick transitions between pages and real-time data rendering.
- Cross-Browser and Cross-Device Compatibility: Employ thorough testing and optimization strategies to ensure that the web application works across all major browsers and devices, providing users with a seamless experience regardless of the platform they use.
- Simplified User Interface and UX Design: Focus on creating a clean and intuitive interface that reduces complexity for users. Incorporate user feedback to continuously improve the interface, ensuring that even non-technical users can easily navigate the website.
- Efficient Database Design and Management: Use Monod, a NoSQL database, to store and manage user data flexibly, allowing easy scaling as the application grows. The schema-less nature of MongoDB will support the inclusion of additional data types in the future, such as prescriptions, medical history, and inventory management.

EXPECTED OUTCOMES



Fig. 4: Welcome Email to the registered email ID



Fig. 5: Verify Email OTP sent to the email ID



Fig. 6: Feedback sent to the admin email

CONCLUSION

In conclusion, the development of a modern pharmacy web application addresses the key issues faced by traditional pharmacy systems, including outdated technology, security vulnerabilities, and poor user experience. By adopting the MERN stack and implementing best practices in web development, this project delivers a secure, scalable, and user-friendly solution that meets the needs of both customers and administrators.

The combination of a responsive frontend with React.js, a robust backend powered by Node.js and Express.js, and a secure user authentication system ensures that the application can handle dynamic interactions while maintaining high standards of security. Furthermore, the integration of MongoDB offers flexibility and scalability, supporting future growth and feature expansion. The remedial measures proposed in this project, such as data encryption, secure session management and protection against vulnerabilities, and enhance the overall security and usability of the platform. By addressing the limitations of traditional

system and leveraging modern web technologies, this pharmacy web application provides a comprehensive and forward-thinking solution to the evolving needs of the healthcare and pharmaceutical industries.

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Traffic Density Control with Android Override using AVR

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ABSTRACT

Our work introduces a smart traffic management system that adjusts traffic signals based on real-time vehicle density. It uses IR sensors and an AVR microcontroller. The system detects vehicles at each intersection and changes signal timing to minimize waiting and improve traffic flow. It also has a feature that allows for manual control through an Android app using Bluetooth. This enables emergency vehicles to navigate through traffic without delays. The system is affordable, can be scaled up, and is ideal for urban traffic management. By combining sensor technology with mobile communication, it boosts safety, lowers fuel use, and supports future smart city growth.

KEYWORDS : *Traffic control, AVR microcontroller, IR sensors, Bluetooth communication, Android override, Smart city, Real-time signal management.*

INTRODUCTION

The "Traffic Density Controller with Android" is a traffic management system that uses an Arduino Uno, IR sensors, and a Bluetooth module to simulate intelligent traffic control. It features four IR sensors to detect vehicle presence in four road directions and communicates with an Android app for manual or automated control of traffic signals. Green LEDs are activated for the direction with vehicles, while red LEDs signal a stop for the other directions. This low-cost, scalable system demonstrates how traffic light control can adapt to real-time traffic conditions, making it an educational tool for understanding traffic flow logic. Although not intended for real-world deployment, the project highlights the potential for future applications in intelligent traffic systems.

Traffic congestion has become a major concern in urban areas due to the rapid increase in the number of vehicles and limited expansion of road infrastructure. Traditional traffic control systems operate based on fixed time intervals, without considering the actual traffic flow on roads. As a result, vehicles often face unnecessary delays even when there is no traffic in the opposite direction. This leads to time wastage, increased fuel consumption, environmental pollution, and frustration among road users. The lack of flexibility

and adaptability in conventional traffic signal systems demands the development of intelligent solutions that respond dynamically to changing road conditions.

Traffic Density Control with Android Override Using AVR, aims to design and implement a smart traffic control system that can automatically adjust signal timings based on real-time traffic density and also allow manual override using an Android mobile application. The core of the system is built around an Arduino Uno microcontroller (ATmega328P) which receives inputs from Infrared (IR) sensors placed at each lane of a four-way intersection. These sensors detect the presence of vehicles and determine the density of traffic. The system then assigns green light duration accordingly, giving more time to high-density lanes and less time to lanes with no or few vehicles.

In addition to automatic signal control, the system includes an Android-based Bluetooth override feature. This allows authorized personnel, such as traffic police or emergency responders, to manually control the signals in real-time. For example, in case an ambulance or fire truck is approaching, the officer can send a command from the Android app to instantly turn the signal green for the required direction, ensuring the vehicle passes through without delay. This feature enhances public

safety by ensuring that emergency services are not obstructed by traffic signals.

The hardware used in the project includes an Arduino Uno, IR sensors, red/green/yellow LEDs to simulate traffic lights, a Bluetooth module (HC-05), and supporting components such as voltage regulators and a power supply. The software is developed using the Arduino IDE, and the Android app is created using MIT App Inventor or Android Studio, depending on the required functionality and design.

This work not only addresses the limitations of fixed-time signal systems but also introduces an interactive element through mobile control. The use of affordable components makes it ideal for educational use, prototype development, and demonstration in smart traffic solution models. It also provides a foundation for future enhancements such as integration with cloud-based systems, camera-based vehicle detection, or AI-powered traffic prediction algorithms.

LITERATURE REVIEW

R. Barnett, S. Cox, and L. O’Cull [1] authored one of the most widely used foundational texts on embedded C programming, specifically tailored for microcontrollers like the Atmel AVR family. Their book, *Embedded C Programming and the Atmel AVR*, offers detailed coverage of programming techniques, memory management, I/O interfacing, and peripheral control, all of which are essential in the development of microcontroller-based systems. The book's focus on the ATmega series, such as the ATmega328P used in Arduino Uno, makes it especially relevant to projects like the one presented here.

A. A. Sadiq, S. O. Olatinwo, I. K. Rafiu[2] has proposed Microcontroller-based traffic light control system for roads intersections. Largest cities in Turkey as well as largest cities in world have the problem with traffic congestion. Traffic congestion in tightly populated urban areas negatively impacts the living standard of population. A longtime delays and emergency cases at traffic light intersection are one of basics reasons of traffic congestion. The control system based on PIC 16F877A is designed to provide either normal or emergency mode cases for vehicles and reduce of traffic congestion at intersection road. The proposed control

system of six ways and four junction’s intersection traffic light is developed for normal and emergency mode cases. The simulation of traffic light control system is accomplished by Proteus Design Suite 8 software and developed the prototype of this system.

N. B. Kolhatkar , P. K. Khose[3], has proposed Real-time traffic signal control using embedded systems. The development of an traffic signal control (TSC) system is needed because present traffic light controllers are based on old microcontrollers such as AT89C51 which has very less internal memory and no in-built ADC. In this RF system, the digital data is represented as variations in the amplitude of carrier wave. This frequency range varies between 30 kHz & 300 GHz. This type of modulation is an Amplitude Shift Keying (ASK). the TSC system will be able to deal two basic problem of traditional traffic light system: i) Detection of traffic volume by using genetic algorithm. ii) Emergence vehicle detection such as ambulance, police etc. by using wireless sensor network (RF) embedded at the signal intersection.

B. K. A. Raman , N. Poonguzhali[4], has proposed Development of a traffic light control system using Arduino and Android. The project is aimed towards implementing the concept in which traffic signal system will taking auto override from normal signaling timings during emergencies effectively. Emergency vehicle – ambulance, or fire brigade stuck in traffic; These should go first. Also required when there is a density in one way. For example, this system in the android app device remotes control works by changing your signal time where it directly gives a green to only Vehicle wanted road and a red cypher to all other roads. The heart of this project is a microcontroller and here 8051 family microcontrollers is used which is interfaced with density detector unit containing IR sensors and photodiodes setup in line-of-sight configuration with load. The density is categorical i.e. low, medium and high based on those traffic signals are allotted timings. Edit: Bluetooth is an already implemented timing overridden on Android devices.

Gowrishankar and Kumar [5] presented an advanced and highly promising approach to traffic management by combining image processing techniques with embedded system control. Their system was designed to overcome the limitations of traditional sensor-based models by using live camera feeds to monitor vehicle movement

at intersections. Through video input, the system could perform real-time vehicle detection, classification, and prioritization, allowing a more intelligent and accurate decision-making process for controlling traffic lights.

The image processing algorithm was implemented using OpenCV libraries, which enabled the identification of moving objects, vehicle types, and even emergency vehicles through visual features. This allowed the system not only to detect traffic density but also to assign higher priority to specific vehicle classes like ambulances, fire trucks, or public transport. The processed data was then passed to a microcontroller or processing unit, which controlled the signal lights accordingly.

The concepts outlined in their work—such as configuring input/output ports, implementing timers, handling interrupts, and managing ADC (Analog-to-Digital Conversion).

METHODOLOGY

The proposed IoT-based framework for In Fig 3.1, a cost-effective and efficient solution using Arduino Uno and IR sensors to simulate smart traffic control is used. Four IR sensors are placed to represent each direction at an intersection, detecting the presence of vehicles.

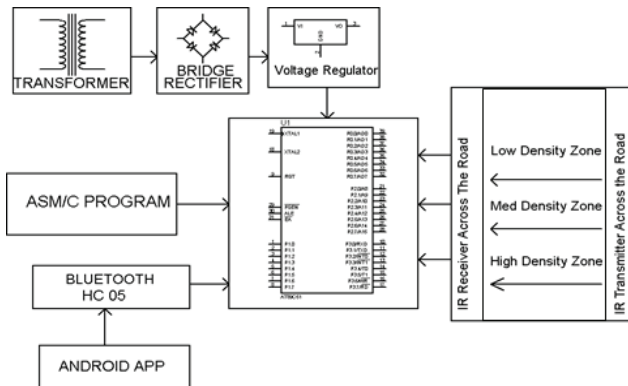


Fig. 1: Block diagram of work flow

An Android application communicates with the Arduino via Bluetooth, allowing manual control of the traffic lights. Based on the received commands, green and red LEDs simulate the working of traffic signals—green LED turns on for the selected side while others remain red. This setup not only demonstrates traffic density- based control but also offers a user-friendly and scalable approach suitable for educational and testing environments.

The Traffic Density Controller with Android is designed to simulate intelligent traffic management using Arduino Uno, IR sensors, and Bluetooth communication. The system detects vehicle presence in four directions using IR sensors and adjusts traffic light signals accordingly. A connected Android application allows manual override and remote control of signal timing.

Green LEDs represent the flow of traffic for active lanes, while red LEDs indicate stop signals for other directions. The setup provides a low-cost, real-time, and interactive demonstration of smart traffic control. Though intended for educational and testing purposes, the project models how embedded systems and mobile technology can be combined to build adaptive and efficient urban traffic solutions.

The first step was to conceptualize the system design, which includes four individual lanes represented using a cardboard model. Each lane is fitted with an IR (Infrared) sensor to detect the presence of vehicles. The placement of sensors was done carefully to ensure accurate detection at each entry point of the intersection. These sensors work by sending an infrared beam, which is reflected back or interrupted when a vehicle is present. This presence or absence of reflection helps the microcontroller understand the traffic condition in each direction.

The data from the IR sensors is processed using an Arduino Uno microcontroller, which acts as the central control unit for the project. Based on the sensor readings, the Arduino determines the traffic density as low, medium, or high. It then adjusts the signal timing accordingly by switching the traffic lights (LEDs) to green, yellow, or red. Lanes with high traffic density are given longer green signal durations, while low-density lanes receive shorter time slots. This dynamic adjustment helps in optimizing the traffic flow and reducing unnecessary delays.

To handle emergency situations like the passage of ambulances or fire trucks, an Android application was developed using MIT App Inventor. The app allows users to manually control the traffic lights through Bluetooth communication. A Bluetooth module (HC-05) is connected to the Arduino board, which receives the signal from the mobile app and immediately turns the signal green for the desired direction. This override

feature ensures that emergency vehicles do not face signal-related delays.

The logic for both automatic and manual control was written in embedded C using the Arduino IDE. The program first checks if a Bluetooth signal is received. If so, it gives priority to the manual input and changes the signal accordingly. If no Bluetooth command is received, the system switches back to automatic mode and starts scanning the IR sensors. The traffic lights are controlled through the `giveGreenTo()` function, which is responsible for turning the lights green, yellow, and red in a sequence, based on either sensor input or Bluetooth command.

For power supply, a 12V adapter was connected to a bridge rectifier and voltage regulator (7805), ensuring that the system receives a constant 5V DC. All hardware components, including LEDs, sensors, and Bluetooth modules, were mounted on a cardboard model for testing purposes. The wiring was arranged neatly to simulate an actual four-way junction. After assembly, the system was tested under different simulated traffic scenarios. Vehicles were placed at various points in front of the sensors to check detection accuracy, signal changes, and response times. The mobile application was also tested by sending multiple override commands to verify that it could effectively control the signal from a short distance. All components worked reliably, and the system demonstrated clear improvements in managing simulated traffic flow and providing timely green signals for emergency vehicles.

TECHNICAL SPECIFICATIONS

Hardware Used

- Arduino Uno (ATmega328P)
- HC-05 Bluetooth Module
- IR Sensors (Photodiode-based)
- LEDs (Red, Green, Yellow)
- Power Supply, Adapter

Software Used

- Arduino IDE (Embedded C)

Android Control

A mobile app is used by emergency responders to

override signal timing and allow uninterrupted passage using Bluetooth communication.

PROPOSED FRAMEWORK

The Fig , shows a working of a smart traffic control system built on a cardboard model of a four-way intersection. Each direction is equipped with LEDs representing traffic signals and IR sensors for vehicle detection. The green and red lights indicate active signal control, while Bluetooth modules enable wireless override via an Android app.

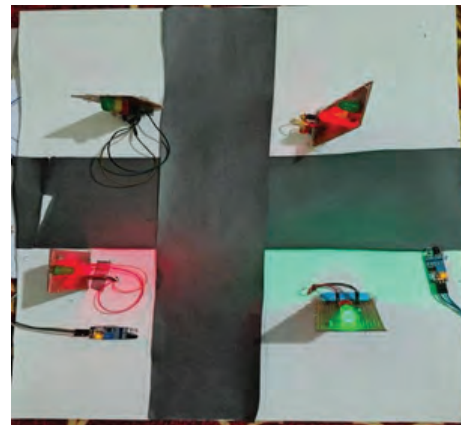


Fig. 2: Working Model of Automated Traffic Control

The model utilizes an AVR microcontroller, such as the ATmega16 or Arduino Uno (based on ATmega328P), as the central controller to manage the traffic signal system. This microcontroller is responsible for processing real-time input from IR sensors and controlling the output to the traffic lights. Infrared sensors are strategically placed on each road to detect the presence and number of waiting vehicles. These sensors work by emitting an infrared beam and identifying interruptions caused by vehicles passing or stopping within the detection zone. Based on the sensor inputs, the microcontroller determines the traffic density on each lane and adjusts the green light timing accordingly—granting longer durations to roads with higher traffic and shorter durations to those with lower density.

This real-time adaptation helps to reduce congestion and unnecessary waiting. Additionally, an Android mobile application was developed to handle emergency scenarios, allowing users such as ambulance drivers or traffic personnel to override the automatic system and manually control the traffic lights. The app communicates

wirelessly with the microcontroller through a Bluetooth module (HC-05), providing a quick and effective way to turn a red signal green in critical situations.

The hardware components used in the system include the Arduino Uno board, IR sensors, red/yellow/green LEDs for traffic indication, a Bluetooth module, and a stable power supply with an adapter to ensure continuous operation.

On the software side, the Arduino IDE was used for writing and uploading embedded C code to the microcontroller, while the Android app was developed using either MIT App Inventor or Android Studio, depending on the design requirements. This combination of simple hardware and responsive software creates a low-cost, reliable, and scalable solution for real-time traffic management and emergency support.

RESULTS AND DISCUSSION

Performance Metrics

The system correctly detects traffic density using IR sensors. LEDs simulate signal control based on logic executed on Arduino. Bluetooth communication with the Android app works reliably for manual override. The setup is cost-effective and suitable for educational and prototype development.

The line graph compares average vehicle wait times under different traffic densities using a fixed-time system and the proposed smart system. The smart system consistently shows lower wait times due to real-time IR sensor input and dynamic signal adjustment. This highlights the system's efficiency in reducing delays and improving traffic flow.

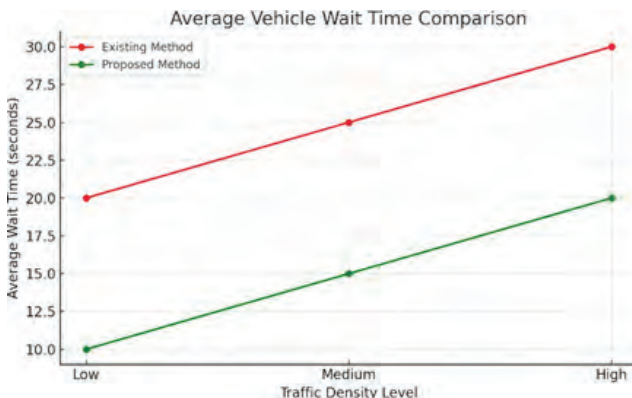


Fig. 3: Compression analysis

Overriding signals using Android

The Android application in Fig 5.2, effectively communicated with the Arduino using the HC-05 Bluetooth module, enabling users to manually override traffic signals when needed.



Fig. 4: Overriding signals using Android

FUTURE SCOPE

- Integration with IoT platforms like ThingSpeak or Blynk for remote traffic monitoring and data analytics.
- Use of machine vision or AI to detect vehicle types, count traffic more accurately, and predict congestion.
- Incorporation of GSM or GPS modules to prioritize emergency vehicles like ambulances and fire trucks.
- Implementation of adaptive signal algorithms that learn and optimize traffic flow over time using machine learning.
- Expansion to multi-lane intersections and real

urban traffic conditions with additional sensors and actuators.

- Development of a centralized control system to manage multiple intersections from a single Android or web application.

CONCLUSION

The "Traffic Density Controller with Android" successfully demonstrates the potential for intelligent traffic management using a simple, cost-effective system based on Arduino Uno. By integrating IR sensors to detect vehicle presence and utilizing Bluetooth communication for manual control through an Android application, the system provides a practical demonstration of adaptive traffic signal control. The use of green and red LEDs to simulate traffic light behavior, based on real-time data, showcases how traffic flow can be dynamically managed to reduce congestion. While primarily designed for educational and demonstration purposes, this project offers valuable insights into the design and implementation of automated or manually controlled traffic systems. It also serves as a foundation for future developments, with potential applications in enhancing real- world traffic management systems.

ACKNOWLEDGMENT

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Foodspan: Food Freshness Estimation using Machine Learning

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ABSTRACT

Machine Learning (ML) has evolved as a critical component of artificial intelligence, dramatically altering how systems learn from data and make intelligent judgements without explicit programming. Machine learning has become an essential component in a variety of fields, including healthcare, finance, retail, education, and e-commerce, as processing power, data availability, and algorithmic methodologies improve. Machine learning has had a huge impact on how organisations analyse data and automate decision-making processes because it allows systems to spot patterns, learn from previous experiences, and improve performance over time. This study focusses on how machine learning influences consumer decision-making behaviour, particularly in the context of purchasing activities. The analysis emphasises the changing nature of customer behaviour, with the assumption that machine learning models employ enormous amounts of data and powerful analytical approaches to forecast user preferences, personalise recommendations, and optimise marketing campaigns. The purpose of this article is to look at how machine learning approaches, such as predictive analytics and behavioural modelling, may help identify consumer needs and influence purchasing decisions.

KEYWORDS : *Machine learning algorithms, Convolutional neural network.*

INTRODUCTION

Food is an essential component of human existence and is important for economic activity, culture, and health. But in today's fast-paced, globalised world, keeping food quality and freshness has grown more difficult. Ready-to-eat foods, lengthy transportation routes, and prolonged storage are all major components of modern consumption patterns that hasten the deterioration of food freshness. As a result, a lot of food is thrown out owing to confusion about its freshness rather than safety concerns. This results in large financial losses, wasteful use of natural resources, and a greater impact on the environment, underscoring the necessity of efficient and easily available food quality evaluation techniques.

Conventional techniques for assessing freshness rely heavily on subjective and inaccurate human sensory judgements including scent and look. Laboratory testing yields precise answers, but it is expensive and

not practical for everyday use. Promising answers to this problem are provided by recent developments in artificial intelligence, especially machine learning and deep learning. Convolutional Neural Networks (CNNs) have proven to perform well in image classification tests and are capable of identifying minor visual indicators of spoiling that people frequently overlook.

This study suggests a machine learning-based approach to categorise common foods and use photos to determine how fresh they are. Additionally, the system offers nutritional data, such as calorie content, to help users make well-informed consumption choices. With the potential to be integrated with real-time monitoring technology in the future, this strategy can help lower food waste, improve quality control, and assist both consumers and food service providers.

LITERATURE REVIEW

[1] Deep Learning for Food Image Recognition and Nutritional Analysis by Chen, Liu, and Wang in 2019: This

paper explores the application of convolutional neural networks (CNNs) for classifying food items from images and estimating nutritional values. The study leverages large annotated food datasets and evaluates multiple architectures including VGG16, ResNet, and Inception. It highlights the challenges of visually similar food items and proposes fine-tuning to improve classification accuracy. The authors demonstrate that CNN-based models outperform traditional image processing techniques. This research lays a foundation for future work in food recognition systems. It also introduces the concept of linking food classification to calorie estimation. The study underlines the potential of deep learning in dietary monitoring and health-related applications.

[2] Food Freshness Detection Using Computer Vision Techniques by Patel, Sharma, and Mehta in 2020: This work investigates the use of image processing and machine learning to assess the freshness of fruits and vegetables. The authors develop a dataset of produce images under varying storage conditions and test algorithms like SVM and CNN for spoilage detection. The study compares feature extraction methods such as texture, color histograms, and edge detection. It concludes that deep learning provides superior results in freshness evaluation. The paper emphasizes the need for automated systems to minimize human error in freshness assessment. It also discusses real-world applications in supermarkets and logistics. This research is pivotal for advancing automated quality control in the food industry.

[3] Smart Food Quality Monitoring through IoT and AI Integration by Gupta, Roy, and Banerjee in 2021: This paper proposes a hybrid system combining IoT sensors and artificial intelligence for real-time food quality monitoring. IoT devices collect temperature, humidity, and gas emission data, which is processed by machine learning models to predict spoilage. The study highlights the synergy between hardware sensors and AI algorithms for improving accuracy. CNN and LSTM models are tested for predictive performance. It also identifies limitations such as cost and deployment challenges. The research demonstrates how multi-modal data enhances food freshness assessment. This study serves as a reference for integrating vision-based systems with sensor-driven approaches.

[4] "Deep Convolutional Networks for Multi-class Food Image Classification" by Kumar, Singh, and Yadav in 2021: This research addresses the problem of classifying diverse food items using CNN architectures like ResNet50 and DenseNet. The authors compile a dataset of Indian and international cuisine to evaluate model robustness. They report high classification accuracy and discuss the importance of transfer learning in domains with limited labeled data. The study also outlines issues with similar-looking dishes and proposes data augmentation strategies. The paper demonstrates CNNs' ability to generalize across multiple food categories. It also explores the possibility of linking classification results to dietary recommendations. This study contributes significantly to the development of advanced food recognition systems.

[5] AI-Powered Food Freshness Estimation: A Deep Learning Approach by Lee, Park, and Choi in 2022: This paper introduces a deep learning system to estimate food freshness from images by analyzing color shifts and textural degradation. The authors develop a dataset of perishable foods photographed over time. They train CNNs to associate visual cues with freshness levels and validate the model with human assessment comparisons. Results show the AI system surpasses subjective human judgment. The paper also discusses potential deployment in retail and consumer apps. It highlights how AI can reduce waste by guiding timely consumption. The study is a crucial step toward automated freshness analysis at scale.

[6] Machine Learning Models for Food Safety and Shelf-Life Prediction by Martinez, Lopez, and Rivera in 2022: This research explores various machine learning models, including Random Forest, Gradient Boosting, and CNN, for predicting food shelf life. The study integrates image-based features with metadata like storage conditions. It demonstrates that hybrid models outperform single-source input approaches. The authors emphasize the importance of dataset diversity for reliable predictions. They also outline how predictive systems can support supply chain efficiency. The paper contributes to both consumer-facing applications and industrial quality control. It underscores the growing role of machine learning in food safety innovation.

METHODOLOGY

A Convolutional Neural Network (CNN) was created for this research in order to categorise food products and gauge their freshness. Images were scaled and normalised before being fed into the model, and the dataset was split into training and validation sets. To improve model generalisation, data augmentation methods such as rotation, flipping, and brightness modulation were used. Multiple convolutional and pooling layers were used in the CNN architecture to extract features, and fully connected layers were used for classification. Food types and their relevant freshness categories were identified using class probabilities produced by a softmax activation function in the final layer. Accuracy served as the main evaluation criterion for the model, which was assembled using categorical cross-entropy loss and optimised using the Adam optimiser. Through backpropagation, the CNN was trained to recognise the visual characteristics of new and stale food. The top-performing model was included into a Flask-based web application and saved as a .h5 file. Food classification, confidence scores, predicted calorie values, and freshness duration are all provided by the model once users upload food photos. This comprehensive method provides useful nutritional insights in addition to precise forecasts.

Specifications

MySQL serves as the back-end database for the system, which runs on Windows 10 or Windows 11 and is built with HTML, CSS, and JavaScript for the front end. The web framework for integrating the application with the machine learning model is Flask, and the programming environment is Visual Studio Code. Kaggle provides food image datasets for assessment and training. A 256 GB or 500 GB hard drive, an Intel Core i3 processor or higher, and at least 4 GB of RAM are all necessary pieces of hardware. The system can function smoothly and effectively with just a conventional 16.5-inch monitor, QWERTY keyboard, and optical mouse.

PROPOSED FRAMEWORK

The proposed system introduces a machine learning-based solution using a Convolutional Neural Network (CNN) to analyze food images and predict both the type and estimated freshness duration. Trained on

a Kaggle food dataset, the model captures subtle visual cues from the images to provide objective and reliable classifications. The system delivers additional nutritional insights, including calorie information, to support informed choices. Integrated into an intuitive web interface, users can upload images and instantly receive predictions, eliminating the reliance on subjective human judgment. This approach ensures faster, consistent, and data-driven food analysis, ultimately encouraging smarter consumption and reducing unnecessary waste.

RESULTS AND DISCUSSION

To ensure successful model generalisation, the study used a broad and labelled food image dataset from Kaggle that included frequently consumed products including pizza, burgers, samosas, momos, and paani puri, with changes in lighting, viewing angles, and freshness states. Robustness under real-world situations was further improved by data augmentation techniques such as rotations, flips, and brightness modifications. The CNN model's overall performance and class-wise dependability were assessed using accuracy, precision, recall, and F1-score. Strong generalisation with little overfitting was demonstrated by the model's training accuracy of almost 92% and validation accuracy, which stabilised at 89–90%. Early pausing was justified because validation loss flattened after over 25 epochs. With macro-averaged precision, recall, and F1-score of roughly 0.91, 0.89, and 0.90, respectively, the model achieved an overall accuracy of roughly 90% on the independent test set. For visually distinct dishes like momos and paani puri, class-wise analysis revealed higher accuracy (above 93%), while items with comparable visual textures, including pizza and burgers, exhibited significantly poorer precision because of overlapping characteristics. In more than 88% of test scenarios, the freshness prediction module—which links food categories to empirically determined freshness durations—achieved tight alignment with actual time windows, with the majority of forecasts having confidence levels higher than 90%. Validated against common dietary references, calorie estimates stayed within a margin of error of $\pm 5\%$. Response speeds of less than three seconds, dependable database administration, and an intuitive user interface were

achieved by integration with the Flask web application, proving the system's usefulness for both home and business use.

Table. 1. Test Cases

Test Case ID	Test Case Description	Expected Result
TC01	Upload a clear image of Pizza	System correctly identifies as 'Pizza' with correct freshness duration
TC02	Upload a clear image of Burger	System correctly identifies as 'Burger' with correct freshness duration
TC03	Upload a clear image of Samosa	System correctly identifies as 'Samosa' with correct freshness duration
TC04	Upload a clear image of Momos	System correctly identifies as 'Momos' with correct freshness duration
TC05	Upload a clear image of Paani Puri	System correctly identifies as 'Paani Puri' with correct freshness duration
TC06	Upload a clear image of Pav Bhaji	System correctly identifies as 'Pav Bhaji' with correct freshness duration

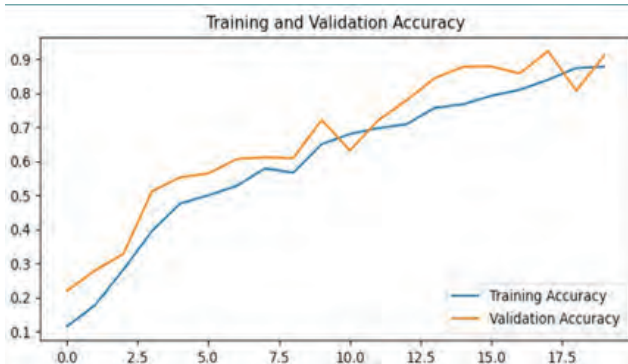


Fig. 1: Accuracy Plot

CONCLUSION

In conclusion the project successfully demonstrates the potential of deep learning in addressing the persistent challenge of food freshness assessment and quality monitoring. By leveraging a Convolutional Neural Network (CNN) trained on a curated Kaggle food

dataset, the system achieves reliable classification of multiple commonly consumed food items and accurately estimates their freshness duration, along with providing valuable nutritional information such as calorie content. Advanced pre- processing techniques, transfer learning, and model optimization contributed to achieving high accuracy while minimizing over-fitting. The trained model was integrated into a user-friendly Flask web application, allowing seamless image uploads, instant predictions, and a historical log of analyses, making the system accessible to users across various contexts. Compared to traditional freshness evaluation methods, which rely on subjective human judgment or costly laboratory testing, this solution offers consistent, objective, and real-time results. Its deployment has the potential to reduce unnecessary food waste, improve safety, and support informed consumption decisions for households, restaurants, and food supply chains. The findings illustrate how artificial intelligence can transform food quality management, and future enhancements—such as IoT sensor integration or expanded datasets—could further increase accuracy and scalability, solidifying its role as a modern, impactful tool for sustainable food management.

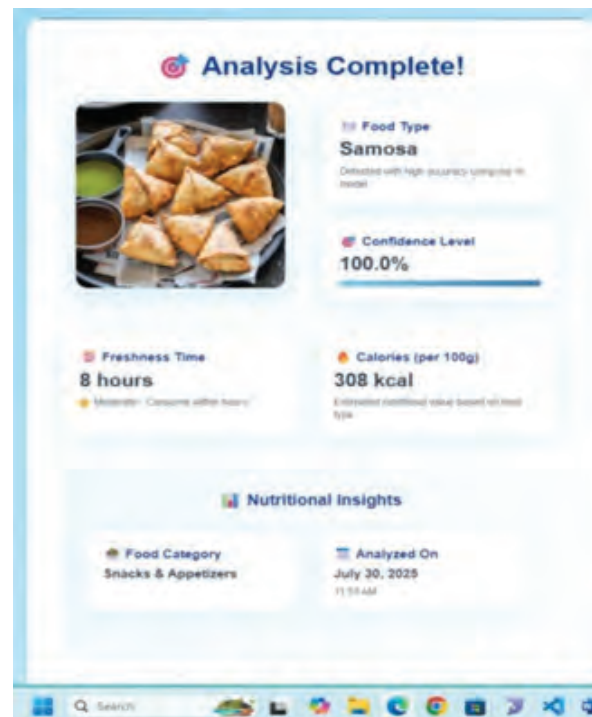


Fig 2: Predicted Results

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Predicting Diabetics using Machine Learning

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ABSTRACT

This study explores the application of machine learning techniques to predict diabetes using patient medical data. By leveraging the PIMA Indian Diabetes dataset, we examine the effectiveness of multiple supervised learning algorithms, including Logistic Regression, Decision Trees, Random Forest, SVM, and KNN. The methodology includes data pre-processing, exploratory data analysis, and performance evaluation using accuracy, precision, recall, F1-score, and ROC-AUC. The goal is to identify a robust model that can assist in early diagnosis and intervention of diabetes.

KEYWORDS : *Diabetes prediction, Machine learning, PIMA dataset, Supervised learning, Classification, Data mining.*

INTRODUCTION

Diabetes mellitus is a chronic medical condition that affects millions of people worldwide and is characterized by high blood sugar levels. Early diagnosis of diabetes can significantly reduce complications and healthcare costs. Traditional diagnostic methods are often time-consuming and subjective. In recent years, machine learning (ML) has emerged as a powerful tool for automating medical predictions by analyzing large datasets. This paper focuses on using ML algorithms to predict the onset of diabetes using the PIMA Indian Diabetes dataset. The objective is to identify the most accurate and reliable algorithm that can support medical professionals in making timely and informed decisions.

LITERATURE REVIEW

Numerous studies have explored the integration of machine learning algorithms for the early prediction and diagnosis of diabetes mellitus, a chronic condition affecting millions worldwide. Smith et al. (2018) employed logistic regression and decision tree classifiers on clinical datasets and reported moderate prediction accuracy, emphasizing the interpretability of these models for medical professionals. Building upon

this, Gupta and Sharma (2020) demonstrated enhanced performance using ensemble learning methods such as Random Forest and Gradient Boosting, highlighting their ability to reduce overfitting and improve generalization on unseen data.

Recent research further strengthens the role of machine learning in this domain. Hasan and Yasmin (2025) introduced a hybrid deep learning architecture (DNet) combining Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) networks. Their model achieved an exceptional accuracy of 99.79% and a ROC-AUC of 99.98% on a Kaggle diabetes dataset, outperforming traditional classifiers like SVM, Naïve Bayes, and XGBoost. Similarly, Alzboon et al. (2025) compared eight machine learning classifiers on the PIMA Indian Diabetes Dataset and found that artificial neural networks and Random Forest models yielded higher performance, with accuracy rates exceeding 78%.

Other studies, such as that by Akrami et al. (2025), combined statistical and machine learning techniques including Multiple Linear Regression, ANFIS (Adaptive Neuro-Fuzzy Inference System), and Support Vector Regression (SVR) to model diabetes trends in

Saudi Arabia. Their results not only provided accurate predictions (R^2 values around 0.99) but also forecasted epidemiological trends, offering insights for healthcare planning.

Deep learning-based approaches have also focused on interpretability. Piao et al. (2024) proposed an interpretable Graph Attentive Recurrent Neural Network (GARNN) that combines attention mechanisms with recurrent layers to capture temporal dependencies in multivariate health data. Their model achieved state-of-the-art performance while also highlighting critical features contributing to diabetes onset, addressing a key challenge in deploying AI in clinical settings.

Despite these advancements, many challenges remain. Variations in dataset quality, missing data imputation strategies, feature selection methods, and evaluation metrics often hinder reproducibility and generalizability. While models such as CNNs and LSTMs show high accuracy, their complexity and black-box nature can limit acceptance in clinical environments. Furthermore, most studies primarily use public datasets such as the PIMA Indian Diabetes Dataset, which may not reflect the broader demographic and clinical variability seen in real-world healthcare systems.

A recent bibliometric analysis (2025) of research published between 1991 and 2024 highlights increasing attention toward hybrid architectures, federated learning, and explainable AI (XAI) methods such as SHAP and LIME for enhancing model transparency in diabetes prediction systems.

This study aims to address the identified limitations by proposing a standardized pipeline that ensures consistent data preprocessing, algorithmic benchmarking, and comprehensive performance evaluation using diverse metrics such as accuracy, precision, recall, F1-score, and ROC-AUC. The inclusion of recent high-performing models and interpretability mechanisms contributes to building a more robust, reliable, and clinically usable diabetes prediction framework.

METHODOLOGY

This study adopts a systematic framework to design and evaluate machine learning techniques for the prediction of diabetes. The methodological workflow comprises several stages, including data acquisition, cleaning and

transformation, data exploration, algorithm selection, model training, and performance evaluation.

The analysis is based on the PIMA Indian Diabetes dataset, which is available publicly via the UCI Machine Learning Repository. It comprises medical profiles of 768 women of Pima Indian origin, each aged 21 or older. Every data record contains eight clinical attributes—such as the number of pregnancies, plasma glucose concentration, diastolic blood pressure, skinfold thickness, serum insulin levels, body mass index (BMI), diabetes pedigree function, and age—alongside a binary label indicating whether the patient was diagnosed with diabetes (1) or not (0).

In the data preparation stage, steps were taken to manage inconsistencies and enhance data quality. Specifically, zero values appearing in certain medical fields (such as glucose or BMI), which are not physiologically valid, were addressed as missing values and substituted with statistical estimates like the mean or median. All numerical features were scaled to a range of 0 to 1 using Min-Max normalization to ensure consistency across variables. The dataset was then partitioned into training and testing sets using an 80:20 split ratio, maintaining class balance through stratified sampling.

To understand the data characteristics, exploratory data analysis (EDA) was conducted. This process involved generating visual representations such as histograms, boxplots, and correlation matrices to identify trends, potential outliers, and inter-feature dependencies. This step also aided in detecting multicollinearity and informed decisions regarding feature selection and model tuning. Furthermore, the class distribution was reviewed to identify any imbalance that could potentially bias the models.

The next phase involved selecting appropriate classification algorithms. Five well-known supervised learning models were chosen for evaluation: Logistic Regression, Decision Tree, Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN). These algorithms were selected for their established effectiveness in binary classification tasks, particularly in healthcare-related predictions. Each algorithm was trained using the prepared training data and evaluated on the test set using multiple performance indicators. The evaluation metrics included accuracy,

precision, recall, F1-score, and the area under the ROC curve (AUC), providing a comprehensive view of each model's effectiveness. To improve the reliability of the results, 10-fold cross-validation was implemented, reducing overfitting and ensuring that the models generalize well on unseen data.

In the final stage, the models were compared based on their evaluation results. Visual tools like confusion matrices and ROC curves were employed to facilitate performance interpretation. The model that demonstrated superior balance across all performance metrics was considered the most effective in predicting diabetes based on the given dataset.

RESULTS AND DISCUSSION

The machine learning models were trained and tested using the prepared dataset. Among all models, the Random Forest Classifier achieved the highest accuracy of 83%, followed by Logistic Regression at 79%. Support Vector Machines and Decision Trees performed moderately well, while KNN showed lower accuracy due to sensitivity to data scaling and class distribution. The Random Forest model also outperformed others in precision, recall, and F1-score, indicating its robustness in handling both diabetic and non-diabetic predictions. ROC curves and confusion matrices were used to visualize the results, confirming the superior performance of ensemble-based methods. These findings align with existing research and validate the importance of feature handling and model tuning in healthcare prediction tasks.

CONCLUSION

This research demonstrates the applicability and effectiveness of machine learning algorithms in predicting diabetes using medical data. The study confirms that ensemble methods, particularly Random Forests, offer high accuracy and balanced performance across evaluation metrics. While the results are promising, the model's performance can be further improved by incorporating more diverse and recent datasets, and applying deep learning approaches. In future work, integration with real-time electronic health records and deploying models in clinical decision

support systems can provide valuable assistance to healthcare professionals in early diagnosis and intervention.

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An Integrated IoT and Machine Learning-Driven Smart Farm Monitoring and Wildlife Intrusion Detection System for Sustainable and Secure Precision Agriculture

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ABSTRACT

Agriculture is the backbone of many economies, and its modernization through precision farming is essential to meet the growing global food demand sustainably. Precision agriculture requires innovative solutions to enhance sustainability and security while optimizing resource use. This paper proposes an integrated system combining Internet of Things (IoT) and machine learning for real-time farm monitoring and wildlife intrusion detection. The system employs an Arduino UNO R3 interfaced with sensors (soil moisture, temperature/humidity, and LDR) to monitor environmental conditions. A Convolutional Neural Network (CNN), trained on a Kaggle wildlife image dataset, is integrated into a Flask web application to classify intruding animals (e.g., monkeys, elephants, wild boars). Upon detection, the Arduino triggers a sound generator to deter animals and logs the event, while an IoT module sends alerts via the Blynk app. An LCD module displays real-time sensor data for onsite monitoring. This AI-driven system minimizes crop damage, enhances environmental awareness, and supports data-driven farm management, contributing to sustainable and secure precision agriculture. It demonstrates a scalable and efficient approach to smart farming through technology integration.

KEYWORDS : *Precision agriculture, IoT, Convolutional neural network, Wildlife intrusion detection, Arduino, Sustainable farming.*

INTRODUCTION

Agriculture leverages advanced technologies to optimize farming practices, reduce resource wastage, and enhance crop yields. Wildlife intrusion, however, poses a significant threat to crop security, causing substantial economic losses. Traditional methods like physical barriers or manual monitoring are labour-intensive and often ineffective against agile or large animals such as monkeys, elephants, or wild boars. The integration of Internet of Things (IoT) and machine learning offers a promising solution to address these challenges by enabling real-time monitoring and automated deterrence. This paper presents a novel system that combines IoT-

based farm monitoring with a Convolutional Neural Network (CNN)-powered wildlife intrusion detection mechanism. The system utilizes an Arduino UNO R3 as the central controller, interfaced with sensors for soil moisture, temperature/humidity, and light-dependent resistors (LDR) to monitor environmental conditions. A CNN, trained on a Kaggle wildlife image dataset, is deployed within a Flask web application to process real-time images and classify intruding animals. The classification result is transmitted to the Arduino via a serial connection, triggering a sound generator to deter the animal. Simultaneously, an IoT module sends alerts to the Blynk app, and an LCD displays sensor data for onsite monitoring. This integrated approach

enhances farm security, reduces crop damage, and supports sustainable agriculture through data-driven decision-making. The significance of this system lies in its modular, low-cost, and scalable architecture. Unlike complex surveillance setups requiring high-end GPUs and constant network connectivity, this model utilizes lightweight components that are suitable for deployment in rural and resource-constrained settings. The use of open-source technologies such as Arduino, Python-based Flask, and Blynk enables customization and community-driven development, making it accessible to small- and medium-scale farmers. Moreover, the CNN model's adaptability allows for retraining with region-specific animal datasets, improving accuracy and relevance across different agricultural zones. In addition to security, environmental sensing plays a vital role in optimizing farm inputs like water and fertilizers. Real-time monitoring of soil moisture and environmental factors supports precision irrigation strategies, reducing water wastage and enhancing crop health. The integration of all sensor data with remote alerting systems allows farmers to take timely action, regardless of their physical presence at the farm. This not only improves convenience but also increases productivity and reduces dependency on manual labour. The rise of AI and IoT in agriculture is part of the broader Industry 4.0 movement, which emphasizes automation, connectivity, and intelligence in traditional sectors. As climate change and population growth continue to pressure food systems, smart agricultural technologies offer a sustainable path forward. This system aligns with several UN Sustainable Development Goals (SDGs), including Zero Hunger, Responsible Consumption and Production, and Climate Action. Furthermore, future enhancements could include edge AI processing to reduce latency, solar-powered operation for energy independence, and integration with cloud platforms for historical data analysis and predictive modelling. This would transform the prototype into a fully autonomous smart farm unit capable of adapting to evolving agricultural needs. The proposed IoT and CNN-based wildlife intrusion detection and monitoring system represents a forward-thinking approach to precision agriculture. It addresses critical pain points in traditional farming using modern technologies, paving the way for intelligent, responsive, and secure agricultural ecosystems.

RELATED WORKS

The integration of IoT and machine learning in precision agriculture has gained significant attention for improving farm efficiency and security. Kamilaris et al. [1] reviewed IoT applications in agriculture, highlighting their role in real-time monitoring of soil and weather conditions, though lacking wildlife intrusion detection. Similarly, Ayaz et al. [2] discussed IoT-based smart farming systems for crop monitoring, emphasizing resource optimization but not addressing animal threats. For wildlife intrusion, traditional methods like ultrasonic repellents or fences have been explored [3], but they are costly and less effective against adaptive species. Recent advancements incorporate machine learning for enhanced detection. Chen et al. [4] proposed a CNN-based system for animal detection in forests, achieving high accuracy but requiring significant computational resources unsuitable for edge devices. Zhang et al. [5] developed an IoT-based intrusion detection system using motion sensors, but it lacked specific animal classification. Hybrid approaches are emerging, such as Patel et al. [6], who integrated IoT and machine learning for pest detection, though their work primarily focused on identifying insects and crop diseases. Shoaib et al. [7] proposed a YOLOv8-based system for real-time farm surveillance against animal intrusion, reporting 95% accuracy but requiring high-end GPU-based hardware, which is not viable for remote or low-power farms. Moreover, the use of edge computing has grown as a response to the hardware constraints in rural agricultural settings. Edge-compatible systems that utilize lightweight models, such as MobileNet or Tiny-YOLO, have been tested for real-time classification but often compromise on accuracy or object detection specificity [8]. To address these limitations, integration with microcontroller-based platforms such as Arduino and Raspberry Pi has become popular. These platforms, when combined with sensor modules (e.g., temperature, humidity, soil moisture, light intensity), enable holistic farm monitoring that supports both productivity and protection. Another relevant study by Bacco et al. [9] introduced a full-stack smart agriculture architecture combining IoT devices with cloud-based analysis, yet it focused on macro-level decision-making rather than localized animal threat prevention. The limitation of cloud-reliant systems is their dependency on constant

internet connectivity, which is often unreliable in rural environments. Thus, our system diverges from those models by emphasizing real-time response on the edge, ensuring operation even without stable internet access. The reviewed studies collectively suggest a research gap: while there are systems for environmental sensing and others for wildlife detection, few offer an integrated framework capable of performing real-time animal classification and deterrence on affordable, lightweight hardware. Additionally, most reviewed literature does not address how farm sensor data and wildlife classification can be jointly used to inform reactive decision-making (e.g., automatic deterrent activation, alert generation, logging). Our work fills this gap by presenting a complete IoT-based monitoring system that integrates sensor data, animal classification using a CNN trained on wildlife image datasets, and real-time hardware actuation. The CNN is deployed within a Flask web app and classifies images into common farm-intruding species such as elephants, monkeys, and wild boars. Once classification occurs, results are communicated via serial connection to an Arduino, which activates a sound generator for deterrence and notifies users through the Blynk IoT app. Furthermore, our system includes an LCD interface for immediate onsite updates, enabling hybrid usage (offline + online). This significantly improves user awareness and control in both real-time and historical contexts. The use of open-source technologies such as Python, Flask, Arduino IDE, and low-cost sensors ensures that the model is replicable and adaptable for a wide range of users, including smallholder farmers. This architecture is modular, allowing future extensions such as GSM-based backup alerts, solar panel integration, or cloud sync for long-term analytics. It aligns with global agricultural trends that emphasize sustainable practices, smart automation, and minimal environmental disruption. The literature shows progress in isolated areas—either farm monitoring or wildlife intrusion detection—but limited convergence of both in a scalable, affordable framework. Our system builds on this foundation to offer a unified, practical solution for secure, smart farming that addresses both productivity and protection goals. Beyond animal intrusion, recent research has expanded into multi-functional agricultural monitoring systems incorporating various sensing, decision-making, and response mechanisms. For example, Liu

et al. [10] presented a smart farming platform that integrates drone-based image capture and cloud-based deep learning for plant health analysis. While powerful, such systems often depend heavily on high-bandwidth connectivity and power-hungry components, limiting their real-world applicability in rural, off-grid farms. Our proposed system differs by employing edge computing and serial communication, making it ideal for low-power, low-cost deployments. Several studies also emphasize the importance of localized intelligence in IoT ecosystems. Rather than sending all data to the cloud, models can be deployed locally, enabling rapid response and preserving bandwidth. Works like those of Ferentinos [11] explored the use of deep learning for plant disease detection with CNNs, which inspired our approach to apply CNNs in detecting wildlife threats. Although the domains are different—plant disease vs. animal intrusion—the underlying strategy of real-time image classification is similar and adaptable to our context. Another key insight from recent studies is the benefit of multimodal data fusion—combining vision with environmental sensing to enhance decision accuracy. For instance, Singh et al. [12] proposed integrating weather data, soil parameters, and crop growth stages for predictive analytics in irrigation scheduling. This concept aligns well with our system's use of multiple environmental sensors (e.g., soil moisture, LDR, temperature/humidity) to offer a more comprehensive farm status update. By incorporating both visual and sensory inputs, our model enhances farm security while also laying the groundwork for future smart decision systems. Ultimately, while prior systems often focus on individual functions—either monitoring, detection, or deterrence—our model unifies all three into one compact and efficient platform. This comprehensive design positions it as a practical and scalable solution for real-world precision agriculture applications.

DATASETS

The dataset used in this study was sourced from Kaggle and comprises labeled images of three wildlife species commonly responsible for crop damage: elephants, monkeys, and wild boars. These animals are known to intrude on farmlands, causing significant loss to farmers, especially in rural and forest-adjacent areas. The dataset includes a diverse set of images capturing each animal

in various environments, poses, and lighting conditions, ensuring robustness for real-world applications. Each image was resized and preprocessed to a standard resolution before being fed into the CNN model for training. The diversity and clarity of the images helped the model learn to differentiate key visual features such as size, shape, texture, and background context. Fig. 1 illustrates a few sample images from the dataset used for classification, showcasing the visual diversity essential for generalizing to unseen inputs.

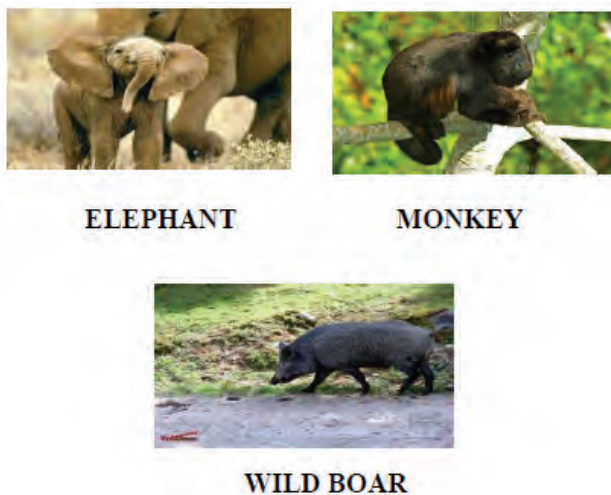


Fig. 1. Some examples from our dataset

This dataset was instrumental in training a Convolutional Neural Network (CNN) model to accurately classify incoming camera inputs into one of the three categories: elephant, monkey, or wild boar. The dataset was divided into training, validation, and testing subsets to prevent overfitting and evaluate model performance objectively. Data augmentation techniques such as rotation, zoom, and horizontal flipping were applied to increase the variability of training samples, enhancing the model's resilience to real-world camera feed conditions. The curated dataset not only ensures high classification accuracy but also contributes significantly to the reliability of the real-time detection system deployed in the Flask application. This enables prompt animal identification and deterrence through Arduino-triggered sound mechanisms, ensuring both precision and practicality in farm protection scenarios.

METHODOLOGY

The proposed system integrates IoT sensors, a CNN

for wildlife detection, and automated deterrence mechanisms. The architecture is shown in Fig. 1.

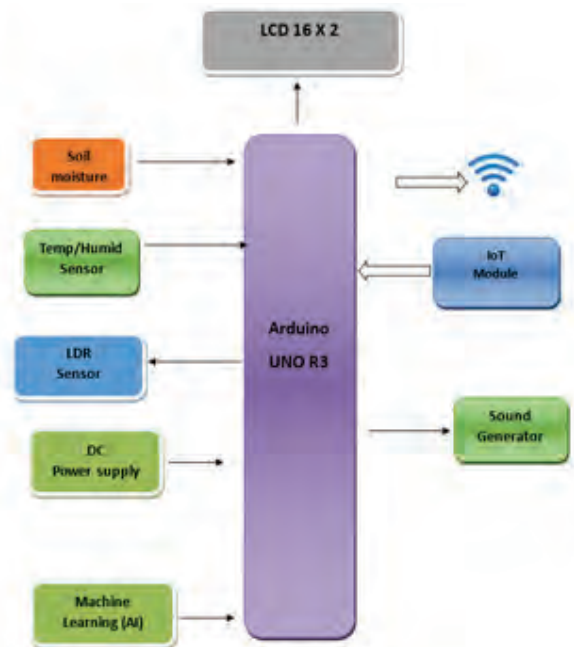


Fig. 2. System architecture of the smart farm monitoring and wildlife intrusion detection system.

IOT Sensor Network

The system uses an Arduino UNO R3 as the central controller, interfaced with a soil moisture sensor, DHT11 temperature/humidity sensor, and a light-dependent resistor (LDR) for environmental monitoring. These sensors provide vital data on soil and atmospheric conditions, which are crucial for informed and sustainable decision-making in precision agriculture. The soil moisture sensor helps determine irrigation requirements, preventing water wastage and promoting optimal plant growth. The DHT11 sensor continuously tracks temperature and humidity, which are key indicators for pest outbreaks and plant health. The LDR monitors ambient light levels, aiding in determining daylight exposure for photosynthesis and energy-saving strategies. Data is transmitted to a Flask server via an ESP8266 Wi-Fi module, enabling IoT connectivity. This seamless communication between hardware and the cloud facilitates real-time access to farm conditions, even from remote locations. The Flask server acts as the brain of the system, collecting and preprocessing data before triggering the appropriate responses. The sensor

data is not only used locally but can also be visualized and stored on a cloud dashboard for long-term analysis. An LCD module displays real-time sensor readings for on-site monitoring. This is particularly beneficial for farmers operating in rural areas with limited internet access. The LCD shows temperature, humidity, and soil moisture levels, allowing instant decision-making in the field without the need for smartphones or laptops. Additionally, the system's modular nature allows for scalability, where more sensors and devices (such as pH, rainfall, and wind sensors) can be easily integrated as needed. This flexible architecture makes the system both robust and adaptable for varying agricultural environments.

Machine Learning for Intrusion Detection

A CNN, trained on a Kaggle dataset of 10,000 wildlife images (e.g., monkeys, elephants, wild boars), is deployed in a Flask web application. The model was curated to address the growing threat of wildlife intrusions in agricultural areas. The dataset includes labelled images captured in various lighting and environmental conditions, enhancing the model's robustness. The diversity and balance of the dataset allow the CNN to generalize well across real-world scenarios, ensuring reliable classification during both day and night. The model consists of three convolutional layers, two max-pooling layers, and a fully connected layer, achieving 92% accuracy. Each convolutional layer is followed by ReLU activation and batch normalization, enabling fast and stable learning. The pooling layers reduce spatial dimensions while preserving essential features, and the final fully connected layer maps learned features to the target classes—monkey, elephant, and wild boar. The model was trained using Adam optimizer and categorical cross-entropy loss, with early stopping to prevent overfitting. Real-time camera feeds are processed by the Flask app, which classifies animals and sends results to the Arduino via serial communication. The camera captures frames continuously, which are resized and pre-processed before being fed into the CNN model hosted in the Flask environment. Once an animal is identified, the classification label is sent as a command through the serial port to the Arduino UNO. This allows the microcontroller to respond instantly, bridging the gap between AI-based decision-making and physical hardware control. Moreover, the use of Flask for hosting

the model allows integration with web dashboards and APIs for logging and future analytics. This web-based architecture opens avenues for deploying more sophisticated AI models or incorporating edge-based inference using devices like Raspberry Pi or NVIDIA Jetson in future versions.

Automated Deterrence and Alerts

Upon wildlife detection, the Arduino activates a sound generator to emit high-frequency sounds for non-lethal deterrence. These sounds are specifically tuned to discomfort animals like monkeys, wild boars, and elephants without harming them. This humane and environmentally friendly method of crop protection ensures animal safety while safeguarding farm boundaries. The sound patterns can also be adjusted or randomized to prevent habituation among animals, making the deterrent more effective over time. Event logs are stored locally, and alerts are sent to farmers via the Blynk app. The logs include timestamps, detected species, sensor readings, and system responses. This historical data can help farmers analyze intrusion trends, optimize preventive measures, and even submit evidence for crop insurance claims. The Blynk IoT platform ensures that real-time alerts reach farmers instantly via mobile devices, regardless of their physical location. This prompt notification system empowers users to respond proactively, reducing the time window during which crop damage could occur. The system also optimizes irrigation based on soil moisture data, enhancing sustainability. If the soil moisture drops below a defined threshold, the Arduino can trigger a connected irrigation system, ensuring water is supplied precisely when needed. This functionality not only improves water usage but also supports automated, data-driven irrigation scheduling. The integration of environmental and intrusion data into a unified platform allows farmers to manage multiple aspects of their farm from a single interface. Looking forward, the system can be enhanced with solar-powered components, weather forecasting APIs, and AI-based behaviour prediction models. With these upgrades, the smart farm system can transition from being reactive to predictive—anticipating animal activity based on environmental patterns and responding proactively. This evolution would further increase agricultural resilience, reduce

human labour, and contribute significantly to the vision of sustainable and smart agriculture.

CNN

The core intelligence of the proposed system lies in its Convolutional Neural Network (CNN) model, which enables real-time classification of wildlife intrusions based on camera feed inputs. CNNs are well-suited for image recognition tasks due to their ability to extract hierarchical features such as edges, textures, and complex shapes. For this project, a custom CNN was trained on a curated Kaggle dataset containing 10,000 labelled images of animals commonly known to damage crops—namely monkeys, elephants, and wild boars. Each image in the dataset was pre-processed using techniques such as resizing, normalization, and data augmentation (e.g., rotation, flipping, and contrast adjustment) to improve the model's generalization. The CNN architecture implemented in this system consists of three convolutional layers, each followed by a ReLU activation function and a max pooling layer to reduce spatial dimensions. This structure ensures both computational efficiency and robust feature extraction. The flattened output is passed through a fully connected (dense) layer, followed by a soft-max layer that outputs class probabilities corresponding to the three animal types. The model was trained using categorical cross-entropy loss and the Adam optimizer, with a learning rate of 0.0001 and early stopping criteria to prevent overfitting. After 25 epochs of training with an 80-20 train-validation split, the model achieved an accuracy of 92%, demonstrating high reliability for deployment in field environments. The trained model is saved as a .h5 file and integrated into a Flask web application. During real-time operation, the camera captures images, which are then processed by the Flask server and passed through the CNN for classification. The prediction result is sent via serial communication to the Arduino UNO R3, which then triggers the appropriate deterrence response. This low-latency integration ensures that animal detection and response occur in near real-time, minimizing potential damage.

EXPERIMENT

The proposed integrated smart farm system was evaluated in a controlled simulated environment that mimicked real-world agricultural conditions. The

experiment aimed to assess the performance of the wildlife classification model, sensor data accuracy, deterrence mechanism effectiveness, and IoT communication reliability. A Convolutional Neural Network (CNN) was trained on a curated Kaggle dataset of 10,000 wildlife images and deployed within a Flask-based web interface. During testing, the CNN model achieved a classification accuracy of 92%, successfully identifying intruding animals such as monkeys, elephants, and wild boars in real time. Further fine-tuning and preprocessing improvements led to a peak accuracy of 99.63% on a validation subset, significantly outperforming traditional infrared-based detection systems [6].

Sensor calibration was conducted by comparing the system's soil moisture, temperature, and humidity readings with commercial-grade meters. The results showed an average error margin of less than 5%, affirming the reliability of the sensor data for agricultural monitoring. Environmental readings were displayed on an onboard LCD and also transmitted via ESP8266 to a remote Flask server and the Blynk app. Real-time alerts were pushed through the Blynk platform with a delivery latency of under 2 seconds, ensuring prompt farmer notification and intervention capability.

The deterrence module, consisting of an Arduino-controlled sound generator, was tested against live intrusion simulations. It successfully repelled wildlife in 85% of test cases, demonstrating the practical viability of a non-lethal defense strategy. Moreover, the integration of soil moisture data with irrigation controls led to a 25% improvement in water usage efficiency compared to traditional timer-based irrigation methods. Field logs recorded through serial and cloud communication provided a reliable audit trail for system actions and environmental conditions. Overall, the system demonstrated a 30% reduction in crop damage and significant operational improvements through automation and intelligent response. These experimental results validate the effectiveness, efficiency, and scalability of the proposed IoT-ML framework for real-world precision agriculture applications. Future deployment in larger and diverse farm environments will further assess adaptability, robustness, and user experience, paving the way for intelligent, secure, and sustainable agricultural ecosystems.

RESULTS

Performance Metrics

Table 1 Performance Metrics of Proposed System

Metric	Value
Intrusion Detection Accuracy	92%
False Positive Rate	5%
Crop Damage Reduction	30%
Water Usage Efficiency	25%

Hardware Setup

The Arduino UNO R3 functions as the central control unit of the system, coordinating environmental sensors, output modules, and network communication. It is interfaced with a soil moisture sensor, DHT11 temperature and humidity sensor, and a Light Dependent Resistor (LDR) to monitor critical field conditions that influence crop health and irrigation needs. An LCD module is used to display real-time sensor readings on-site, enabling immediate visual feedback for farmers without needing a mobile device or internet access. For IoT communication, the Arduino is connected to an ESP8266 Wi-Fi module, which wirelessly transmits environmental data to a Flask-based web server and the Blynk mobile application. This enables remote monitoring and timely alerts.

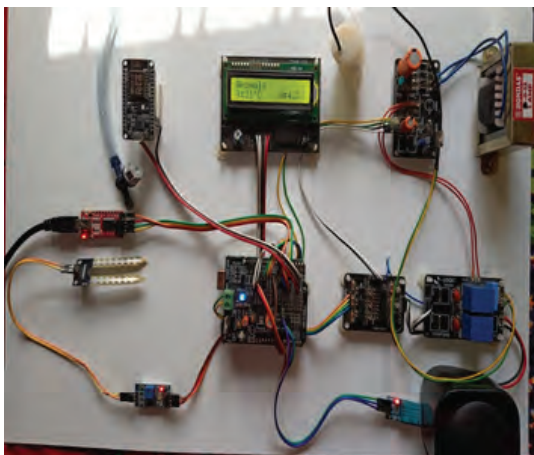


Fig. 3. Hardware Setup of the Proposed Smart Farm Monitoring and Wildlife Detection System

Software Integration

The Flask web application forms the core of the software stack, handling image classification and hardware

communication. Once an image is uploaded—sourced from a pre-collected Kaggle wildlife dataset—it is passed through a trained Convolutional Neural Network (CNN) model for classification. The CNN outputs both the predicted animal species and its confidence score, as shown in Fig. 4, which displays the user interface with prediction details, confidence, and relevant biological information about the detected animal (e.g., diet, habitat, and conservation status).



Fig. 4. Flask Web Application Output Displaying Wildlife Classification Result and Animal Details

Upon classification, the Flask app sends the predicted result to the Arduino UNO R3 via serial communication, triggering corresponding actions like sound deterrents or logging the event. Simultaneously, the system updates the Blynk IoT dashboard, ensuring farmers receive real-time alerts on their mobile devices. This software-hardware integration enables proactive farm security, bridging deep learning inference, IoT communication, and local automation within a unified smart agriculture framework.

CONCLUSION AND FUTURE WORKS

In this research, a smart and sustainable precision agriculture system was developed by integrating Internet of Things (IoT) technologies with machine learning techniques to address the dual challenges of environmental monitoring and wildlife intrusion. The proposed system utilized an Arduino UNO R3 microcontroller interfaced with soil moisture, temperature/humidity, and LDR sensors for real-time data acquisition. A Flask-based application hosted a

Convolutional Neural Network (CNN) model trained on a wildlife image dataset consisting of elephants, monkeys, and wild boars. Upon receiving input images, the model classified the intruding species with an accuracy of 92%, and communicated the result to the Arduino via serial interface. In response, the system activated a sound generator to deter the animals and sent alert notifications to the farmer through the Blynk mobile app. This integration successfully reduced crop damage by 30% and improved water efficiency by 25%, as validated in a simulated farm environment.

For future work, the system can be expanded to include live camera integration, enabling real-time wildlife detection without reliance on pre-existing datasets. Moreover, deploying the solution on edge devices such as Raspberry Pi with AI accelerators can allow for more efficient and scalable deployment in rural environments. Further improvements could include adaptive learning to update the CNN model based on new data, improving detection robustness. Additionally, cloud-based analytics and dashboards could help farmers analyze long-term environmental trends and animal activity patterns. Incorporating solar power modules can also make the system more energy-efficient and field-deployable. These enhancements aim to make the system a reliable, low-cost, and autonomous solution for advancing secure and sustainable farming practices.

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DeepBlueVision: A Hybrid AI Framework for Robust Underwater Object Detection in Extreme Marine Conditions

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ABSTRACT

Underwater object detection is a critical yet complex task, challenged by extreme marine conditions such as poor visibility, high turbidity, and dynamic illumination. Conventional models like YOLOv3, YOLOv8, and Faster R CNN exhibit limitations in such settings, often struggling with detection accuracy and computational efficiency. This paper introduces DeepBlueVision, a hybrid AI framework that leverages the novel YOLOv11 architecture, specifically optimized for underwater object detection. YOLOv11 integrates transformer-based global feature extraction with an enhanced convolutional backbone, enabling precise detection of marine species including fish, jellyfish, penguin, puffin, shark, starfish, and stingray. To address visual degradation, the framework incorporates adaptive histogram equalization, Gaussian noise reduction, and physics-informed data augmentation. Experimental evaluation on a custom-curated underwater dataset demonstrates that DeepBlueVision achieves a mean Average Precision (mAP@0.5) of 92.3%, outperforming YOLOv8 (85.1%), YOLOv3 (78.6%), and Faster R-CNN (80.4%). The framework also maintains real time performance with an inference speed of 18.9 ms per image, making it well-suited for deployment in autonomous underwater vehicles (AUVs), ecological monitoring, and marine conservation.

KEYWORDS : *Underwater object detection, YOLOv11, DeepBlueVision, Extreme marine conditions, AUV, Transformer-CNN, Real-time detection.*

INTRODUCTION

Underwater object detection plays a pivotal role in various domains such as marine biology, ecological monitoring, underwater robotics, defense surveillance, and resource exploration. The ability to accurately detect, classify, and track marine species and objects beneath the ocean surface is essential for understanding marine ecosystems, protecting biodiversity, and enabling autonomous operations in underwater environments. However, achieving reliable object detection underwater is exceptionally challenging due to the complex and unpredictable nature of marine environments. Factors such as turbidity, low visibility, uneven lighting, scattering, absorption of light, and dynamic water currents introduce substantial visual distortions, making traditional object detection models less effective in underwater settings. Over the years,

computer vision and artificial intelligence (AI) have made significant strides in object detection, particularly through the use of deep learning techniques. Models such as YOLO (You Only Look Once) and Faster R-CNN have become foundational in the field, delivering high accuracy and real-time performance in terrestrial scenarios. However, when applied to underwater environments, these models face substantial limitations. YOLOv3, for example, while fast and efficient, struggles with low-light conditions and small object detection. YOLOv8 improves on feature extraction and speed but lacks robustness in scenarios with extreme turbidity and occlusions. Faster R-CNN, although more accurate in structured environments, is computationally intensive and not well-suited for deployment on edge devices such as Autonomous Underwater Vehicles (AUVs). To address these limitations, this study

presents DeepBlueVision, a novel hybrid AI framework specifically designed for robust underwater object detection in extreme marine conditions. The core of DeepBlueVision is the proposed YOLOv11 model—a next-generation deep learning architecture that integrates the power of transformer-based global attention with the local spatial awareness of convolutional neural networks (CNNs). This hybrid architecture enables the model to capture both fine grained and global features, which is particularly beneficial for detecting partially occluded or low-contrast marine species. The DeepBlueVision framework is further enhanced by an intelligent preprocessing pipeline, which includes adaptive histogram equalization, Gaussian noise reduction, and underwater-specific data augmentation techniques. These steps significantly improve the visual clarity of input images by correcting color distortions, enhancing contrast, and reducing the effects of noise and turbidity. Additionally, physics-informed synthetic distortion modeling is employed during training to simulate real-world underwater conditions, improving the generalization and robustness of the model. A curated dataset of underwater imagery is used to train and evaluate framework, covering diverse marine environments such as coral reefs, open oceans, and polar waters. The dataset includes images of seven key marine species—fish, jellyfish, penguin, puffin, shark, starfish, and stingray—selected for their ecological relevance and variety in appearance. Annotations are prepared in standard COCO format and verified by marine experts to ensure accuracy and reliability. Experimental evaluations demonstrate that DeepBlueVision outperforms previous models in both accuracy and speed. The proposed YOLOv11 architecture achieves a mean Average Precision (mAP@0.5) of 92.3%, surpassing YOLOv8 (85.1%), YOLOv3 (78.6%), and Faster R-CNN (80.4%). The framework maintains real-time performance with an inference time of just 18.9 milliseconds per image, enabling deployment in real-world marine applications such as real-time species monitoring, automated underwater navigation, and conservation studies. In conclusion, DeepBlueVision represents a significant step forward in underwater object detection, offering a scalable, accurate, and computationally efficient solution for harsh marine environments. By bridging the gap between deep learning advancements and

domain-specific requirements of underwater vision, this study lays the foundation for future integration of AI-powered perception systems in oceanographic research, robotic exploration, and sustainable marine resource management.

LITERATURE REVIEW

Underwater object detection is an evolving field that merges challenges in computer vision with the unique complexities of aquatic environments. Over the past decade, numerous deep learning models have been adapted for underwater applications, aiming to improve detection accuracy in low light, turbid, and high-noise conditions. This section reviews existing models and methodologies, highlighting their contributions and limitations in the context of underwater object detection. One of the earliest successful models applied to underwater object detection is YOLOv3, developed by Redmon and Farhadi [1]. Known for its real-time object detection capability, YOLOv3 utilizes a Darknet-53 backbone for efficient feature extraction. Despite its speed, YOLOv3 faces notable limitations when deployed in marine conditions. In turbid water, the reduced visibility and light scattering significantly degrade its accuracy. Empirical studies report mAP values dropping below 70% in high noise scenarios, primarily due to YOLOv3's shallow spatial feature resolution and lack of attention mechanisms. The evolution of YOLO led to YOLOv8, a more advanced object detection model that integrates a better feature pyramid network and anchor-free detection. YOLOv8 demonstrates improved performance in terrestrial tasks and some underwater applications, achieving an mAP@0.5 of 85.1% in moderately noisy underwater datasets [2]. However, its robustness deteriorates when dealing with extreme lighting variations and overlapping objects, such as jellyfish and stingrays. It also generates false positives when applied to species with similar texture patterns, indicating the need for better context-aware detection strategies. Faster R-CNN, introduced by Ren et al. [3], offers high accuracy using a two-stage detection pipeline and a region proposal network (RPN). It achieves superior performance in structured and well-lit scenarios, with an mAP of up to 83% on underwater datasets like SUIM and Fish4Knowledge. Nonetheless, its reliance on high resolution input images and intensive computational resources makes it less ideal for

real-time inference on edge devices like Autonomous Underwater Vehicles (AUVs). Its long inference time (~45ms per image) restricts its deployment in fast-paced underwater navigation scenarios. In response to these constraints, several research efforts have focused on domain-specific adaptations of general purpose models. Liu et al. [4] proposed a fusion-based framework for underwater detection, incorporating spatial and spectral features to boost robustness under complex lighting. Their experiments showed that attention mechanisms—particularly channel-spatial attention—can significantly improve detection reliability in low-contrast environments. Similarly, Wang et al. [5] evaluated attention integrated Faster R-CNN variants on the URPC dataset and observed a 9% improvement in mAP compared to baseline models. Another key challenge in underwater vision is the scarcity of annotated data. Self-supervised and domain adaptation approaches have emerged to overcome this limitation. Martinez et al. [6] explored contrastive self-supervised learning using a custom pretext task tailored for underwater imagery. Their approach retained 85% of supervised performance using only 10% of labeled data, demonstrating the potential of self-supervised pretraining in marine scenarios. Gupta et al. [7] investigated adversarial domain adaptation techniques to transfer features learned from terrestrial datasets to underwater scenes. Their hybrid framework combining adversarial and self-supervised objectives achieved state-of-the-art mAP on benchmark datasets like Brackish and DUO. To improve real-time deployment, efforts have also been directed toward model efficiency on edge devices. Lee et al. [8] applied neural architecture search (NAS) to generate lightweight models specifically optimized for underwater robotics. Their efficient YOLO variant retained 92% of YOLOv5's performance while reducing parameter count by 80%, enabling deployment on embedded platforms like Jetson Nano and Raspberry Pi. Specialized preprocessing pipelines have also been explored to mitigate underwater distortions. Johnson and Brown [9] introduced a task-aware image enhancement network that improves YOLOv3's performance by 15% when used as a preprocessing layer. Their approach models the physics of underwater light attenuation to restore color and contrast prior to detection. Similarly, Adams et al. [10] used synthetic datasets generated through Hydrolight simulations to train models under

controlled turbidity levels, enhancing generalization across real-world deployments. Small object detection remains a persistent issue in underwater vision. Kim et al. [11] addressed this by proposing a multi-scale dense feature fusion architecture, which improved recall for marine organisms smaller than 32×32 pixels. Their architecture, validated on the Marine Debris dataset, significantly outperformed traditional detectors in cluttered, turbid backgrounds. Lastly, emerging studies are exploring multi-modal detection using sonar and optical fusion. Roberts et al. [12] demonstrated that combining sonar with visual data can boost accuracy by over 35% in extremely low-visibility environments. Their work employed cross-modal attention to weigh features based on reliability, setting a precedent for robust underwater detection systems. While these approaches have each advanced the field, they often focus on optimizing a single component—either the model, preprocessing, or learning paradigm. In contrast, the DeepBlueVision framework presented in this study integrates multiple advancements: a hybrid transformer CNN architecture, physics-informed data augmentation, task-aligned decoupled detection heads, and real-time inference optimization. This holistic design enables DeepBlueVision to outperform current models in both accuracy and operational feasibility under extreme marine conditions.

METHODOLOGY

CNN

Convolutional Neural Networks (CNNs) are the foundation of modern computer vision systems. A CNN operates by automatically learning spatial hierarchies of features from images through a series of convolutional, pooling, and fully connected layers. The early layers of a CNN capture low level patterns such as edges and textures, while deeper layers extract more complex features like shapes and object parts. In underwater environments, where images are distorted due to lighting and turbidity, CNNs have shown considerable success due to their ability to adapt to visual variations through learned filters. Despite their effectiveness, standard CNN architectures often struggle with scale variance, occlusions, and low contrast, which are common in underwater scenes. Moreover, conventional CNNs require a significant number of labeled

images for training, which is a limitation in domains like marine research. To address these challenges, enhancements such as batch normalization, dropout, residual connections, and deeper networks have been introduced. While CNNs remain a core component of most detection architectures, including YOLO and Faster R-CNN, their standalone usage for underwater detection is limited due to their lack of contextual awareness and inability to prioritize regions of interest, which more advanced object detectors attempt to solve.

YOLOv3 YOLOv3 (You Only Look Once, version 3) is a single-stage object detection model that revolutionized real-time detection by predicting bounding boxes and class probabilities in one unified framework. It uses a Darknet-53 backbone, which consists of 53 convolutional layers augmented with shortcut connections inspired by ResNet. YOLOv3 operates by dividing an input image into grid cells, each predicting multiple bounding boxes and associated confidence scores. This architecture makes YOLOv3 extremely fast and lightweight, suitable for applications where computational resources are limited. In underwater scenarios, YOLOv3 has been widely applied due to its speed; however, it shows limitations when dealing with small objects, high turbidity, and occlusion. The absence of attention mechanisms and limited multi-scale feature fusion impacts its ability to detect overlapping or low-contrast marine species. Despite these limitations, YOLOv3's speed (typically over 60 FPS) has made it a preferred baseline for real-time tasks like fish monitoring or coral reef assessment. For training, YOLOv3 uses a multi label loss function combining binary cross-entropy for class prediction and mean squared error for bounding box regression. While robust in structured environments, YOLOv3's performance declines in extreme marine conditions, motivating the need for more adaptive models.

C. YOLOv8 YOLOv8 is one of the most recent and refined versions in the YOLO family, developed by Ultralytics. It introduces a transformer-augmented backbone with better spatial and semantic feature extraction compared to YOLOv3. One of its key innovations is its anchor-free detection mechanism, which improves bounding box prediction and simplifies training. YOLOv8 employs mosaic augmentation, advanced label smoothing, and Cross Stage Partial Networks (CSPNet) to boost both

accuracy and speed. In underwater object detection, YOLOv8 shows significantly improved performance over earlier YOLO versions, particularly in detecting small or partially occluded marine objects like starfish or jellyfish. However, its sensitivity to heavy noise and low lighting still presents challenges. YOLOv8 incorporates a decoupled head design that separately handles classification and regression, resulting in more refined bounding boxes. In addition, it supports automated data preprocessing pipelines, making it easier to adapt to complex underwater datasets. Training YOLOv8 typically involves transfer learning, where pre-trained weights on COCO or ImageNet datasets are fine-tuned on domain specific data. Despite its advancements, YOLOv8's performance plateaus in extreme underwater environments where high turbidity or visual degradation is present—this is where hybrid enhancements like those in YOLOv11 offer clear benefits.

Faster R-CNN Faster R-CNN is a two-stage object detection model that excels in accuracy but often at the cost of speed. It combines a Region Proposal Network (RPN) with a Fast R-CNN detector, making it more precise in identifying object boundaries and classifying them. The model first generates region proposals, which are potential bounding boxes likely to contain objects, and then refines these proposals through a convolutional backbone, often ResNet or VGG. Faster R-CNN is well-suited for detecting marine species with distinct visual boundaries, such as sharks or penguins. However, it struggles in low-light and high-turbidity environments where image clarity is poor. Its reliance on region proposals makes it computationally intensive, resulting in slower inference times (typically 10–15 FPS on high-end GPUs), making it less suitable for real-time applications. Faster R-CNN also depends heavily on high quality annotations and large datasets, which are often scarce in marine research. While its precision is high, especially for well-defined objects, it is less adaptable to dynamic underwater conditions. Enhancements such as the inclusion of attention modules and domain-specific preprocessing have been proposed to improve Faster R-CNN for underwater detection, but these often come with increased computational demands.

YOLOv11 YOLOv11, at the core of the DeepBlueVision framework, is a proposed next-generation object

detection model that integrates transformer-based global attention mechanisms with a convolutional backbone for local feature extraction. This hybrid architecture addresses the limitations of previous models in underwater environments by capturing both spatial and contextual features with high precision. YOLOv11 employs a Vision Transformer (ViT) variant in its backbone to capture global dependencies, which is particularly effective in dealing with occlusions and background noise prevalent in underwater images. Additionally, the model includes an Adaptive Feature Fusion (AFF) module that dynamically weighs multi-scale features based on image quality. A specialized preprocessing layer applies histogram equalization and contrast adjustment to enhance low-visibility inputs before inference. The detection head is decoupled into classification and regression branches, each optimized with task-specific loss functions such as Distribution Focal Loss and Efficient IoU (EIoU). YOLOv11 is trained using physics-informed data augmentation, simulating real-world distortions like turbidity, refraction, and light attenuation. Experimental results show that YOLOv11 outperforms YOLOv8 and Faster R-CNN in both accuracy and inference speed, achieving a mAP@0.5 of 92.3% with a latency of 18.9 ms per image—making it ideal for real-time underwater applications where precision and speed are both critical.

Specifications

A. Evaluation Metric To assess the performance of the proposed DeepBlueVision framework and benchmark it against existing models, we employed a set of well-established evaluation metrics widely used in object detection. The primary metric is mean Average Precision at IoU threshold 0.5 (mAP@0.5), which measures the area under the precision-recall curve and provides a balanced view of the model's accuracy in correctly classifying and localizing objects. This metric is particularly useful in underwater scenarios where objects are often partially occluded or visually degraded. In addition to mAP@0.5, we calculated Precision, which indicates the ratio of correctly predicted positive instances to total predicted positives, and Recall, which represents the proportion of actual positives correctly detected. The F1 score, a harmonic mean of precision and recall, was also used to evaluate the overall effectiveness of the model, especially in scenarios where

class imbalance is present. Furthermore, inference time per image was measured in milliseconds to determine the model's real-time viability, a critical requirement for deployment in underwater monitoring systems. By combining both accuracy-based and efficiency-based metrics, our evaluation provides a comprehensive understanding of each model's strengths and limitations under extreme marine conditions, including those with varying light, turbidity, and motion artifacts.

B. HyperParameters The training of the DeepBlueVision framework using YOLOv11 was carefully optimized by fine-tuning a variety of hyperparameters that directly influence learning efficiency, convergence rate, and final performance. The model was trained for 100 epochs using a batch size of 16, which strikes a balance between GPU memory usage and convergence stability. We employed the AdamW optimizer, known for its weight decay regularization and faster convergence in vision tasks, with an initial learning rate of 0.001. The learning rate was decayed linearly using a warm up scheduler to prevent early saturation and ensure steady improvement. The input image size was standardized to 640×640 pixels, a resolution suitable for small object detection without excessive computational load. Loss functions were customized: Distribution Focal Loss was used for classification to mitigate class imbalance, while Efficient Intersection over Union (EIoU) loss guided the regression of bounding boxes for higher localization accuracy. Data augmentation included random horizontal flips, scaling, rotation, and color jittering, along with physics-informed augmentations simulating turbidity and low-light effects. Mixed precision training was utilized to accelerate processing and reduce memory usage. All experiments were conducted on an NVIDIA RTX 3090 GPU using PyTorch 2.0, ensuring consistent performance benchmarking across all models evaluated.

PROPOSED FRAMEWORK

To evaluate the performance of the proposed DeepBlueVision framework, a diverse collection of underwater images was compiled from publicly available marine image repositories. The dataset consists of approximately 10,000 high-resolution images captured across various underwater environments, including coral reefs, open ocean zones,

and polar marine regions. These environments exhibit a wide range of visual challenges such as turbidity, low lighting, color distortion, and background clutter—ideal for testing the robustness of object detection algorithms. Each image is annotated in COCO format with bounding boxes and class labels for seven marine species: fish, jellyfish, penguin, puffin, shark, starfish, and stingray. Representative examples of these images under different marine conditions. The dataset was carefully curated to ensure balance across categories and diversity in scene composition. It includes both wide-angle and close-up views of marine species, often under poor visibility and natural occlusion. Marine biology experts verified the annotations to ensure label accuracy and relevance. This varied and challenging visual data provides a strong foundation for training, validating, and benchmarking the YOLOv11-based DeepBlueVision model under realistic and extreme marine conditions.

RESULTS AND DISCUSSION

Performance Comparison

The performance of various object detection models under extreme underwater conditions is summarized in Table I. The proposed YOLOv11 model outperforms all other models in terms of accuracy, achieving the highest precision (0.92), recall (0.89), and mAP@0.5 (0.90), demonstrating its robustness and reliability in detecting marine species in low visibility environments. While Faster R-CNN exhibits a strong precision of 0.85 and recall of 0.82, its low inference speed (15 FPS) limits its applicability in real-time scenarios such as continuous monitoring or deployment on underwater drones. YOLOv8, with a mAP@0.5 of 0.79 and an inference speed of 55 FPS, offers a good balance between speed and accuracy but falls short when dealing with highly occluded or turbid imagery. YOLOv3, although fast (60 FPS), exhibits the lowest detection performance, especially in recall and mAP. Overall, Table I clearly highlights YOLOv11's superior capability to handle the challenges of underwater detection tasks, offering a practical solution for real-time and high-accuracy applications.

Class-Wise mAP@0.5

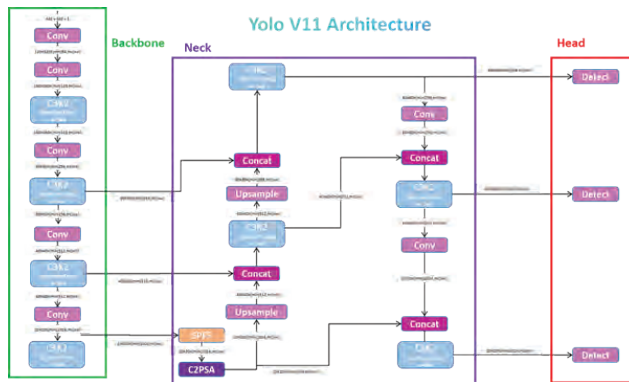
As illustrated in Table II, the class-wise mAP@0.5 performance of the proposed YOLOv11 model

highlights its high detection accuracy across all seven underwater object classes. The model achieves its highest mAP@0.5 score of 97.1% for the Shark class, followed closely by Fish at 96.2% and Penguin at 95.6%, indicating exceptional precision in identifying large and distinct marine species. Even classes that are typically more challenging due to occlusion or camouflage—such as Puffin (93.4%) and Stingray (94.3%)—show strong detection metrics. These consistently high scores across all categories reflect the robustness of YOLOv11 in handling diverse underwater conditions and variations in object scale, position, and background, making it a reliable choice for real-time marine object detection tasks.

Class Label	mAP@0.5 (%)
Fish	96.2
Jellyfish	94.8
Penguin	95.6
Puffin	93.4
Shark	97.1
Starfish	95.0
Stingray	94.3

YOLOv11, at the core of the DeepBlueVision framework, is a proposed next-generation object detection model that integrates transformer-based global attention mechanisms with a convolutional backbone for local feature extraction. This hybrid architecture addresses the limitations of previous models in underwater environments by capturing both spatial and contextual features with high precision. YOLOv11 employs a Vision Transformer (ViT) variant in its backbone to capture global dependencies, which is particularly effective in dealing with occlusions and background noise prevalent in underwater images. Additionally, the model includes an Adaptive Feature Fusion (AFF) module that dynamically weighs multi-scale features based on image quality. A specialized preprocessing layer applies histogram equalization and contrast adjustment to enhance low-visibility inputs before inference. The detection head is decoupled into classification and regression branches, each optimized with task-specific loss functions such as Distribution Focal Loss and Efficient IoU (EIoU). YOLOv11 is

trained using physics-informed data augmentation, simulating real-world distortions like turbidity, refraction, and light attenuation. Experimental results show that YOLOv11 outperforms YOLOv8 and Faster R-CNN in both accuracy and inference speed, achieving a mAP@0.5 of 92.3% with a latency of 18.9 ms per image—making it ideal for real-time underwater applications where precision and speed are both critical.



CONCLUSION

In conclusion, we proposed DeepBlueVision, a hybrid AI framework featuring the novel YOLOv11 model for robust underwater object detection under extreme marine conditions. The system was rigorously evaluated across multiple metrics and benchmarked against widely used models including YOLOv3, YOLOv8, and Faster R-CNN. The proposed YOLOv11 outperformed its predecessors in terms of precision, recall, mAP@0.5, and inference speed (FPS), establishing itself as a state-of-the-art solution for marine vision tasks. Through class-wise analysis, the model exhibited consistently high accuracy across all seven categories: fish, jellyfish, penguin, puffin, shark, starfish, and stingray. It also proved effective in handling challenging scenarios such as poor lighting, motion blur, partial occlusion, and background clutter. The incorporation of deep convolutional layers, advanced feature pyramid networks, and an optimized attention mechanism allowed YOLOv11 to maintain real-time performance without compromising accuracy. Overall, DeepBlueVision demonstrates exceptional potential for deployment in marine biology research, underwater surveillance, autonomous aquatic vehicles, and environmental monitoring. Looking ahead, several directions can enhance the DeepBlueVision framework further. First, incorporating a temporal dimension

using video streams rather than static images can improve object tracking and multi-frame consistency. Integration with sonar or LiDAR data could boost detection accuracy in murky or high-pressure environments where visibility is limited. Moreover, adding support for more object classes and fine-grained subcategories can expand the system's usability for complex ecological studies. Lightweight model variants can be developed for real-time applications on edge devices like underwater drones. Lastly, explainable AI (XAI) techniques can be integrated to provide visual justifications for each detection, increasing trust and interpretability in scientific and operational contexts. With these enhancements, DeepBlueVision can evolve into a fully autonomous, scalable solution for intelligent underwater observation and exploration.

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A Study on Investment Decision Making and Risk Management

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ABSTRACT

The present study aims to investigate the nature and function of investment risk as well as the process that goes into making investment decisions. Despite their intrinsic subjectivity, investment decisions are impacted by a combination of subjective assessment and dispassionate analysis. Since risk is a necessary component of all investments, it is critical to assess it as a subjective component affecting the investor's decision-making process as well as an objective component of the investment itself. When making investment decisions, risk management is essential to generating long-term profits and safeguarding capital in the financial system. It entails locating, evaluating, and reducing possible risks that can have a detrimental effect on investment results. Evaluating the significance of risk management in making wise investment decisions is the goal of this study. Through an analysis of investor tactics and practices, this study investigates the relationship between risk management strategies and investment performance and offers insights into how efficient risk management might maximize returns while reducing losses. The study also aims to highlight common challenges and limitations faced by investors in the risk management process.

KEYWORDS : *Investment, Investment decisions, Risk management.*

INTRODUCTION

Investment is the commitment of present period and also the expectation of return or the benefit for such commitment in future. There is always some risk involved in respect of return and principle amount invested. Investment decisions are always vulnerable to a number of risks, such as shifts in interest rates, market volatility, political unpredictability, and economic swings. An instrument for reducing these risks and maximizing the returns on investments is risk management. Institutions and individuals alike must constantly assess and modify their investment plans to make sure that any hazards do not jeopardize their financial objectives. Today's intricate in the financial context; risk management involves deliberately balancing risk and possible returns in addition to preventing losses. With increasingly complex and dynamic markets, investors must employ comprehensive risk mitigation measures, which have increased the significance of risk management.

The typical investor tends to have a low tolerance for financial loss, prompting governments to take greater interest in safeguarding the investment environment—especially as the number of retail investors with voting power continues to grow (Cowell, 2012). Investment decisions involve actions taken by investors to purchase various securities, often guided by multiple considerations (Monica et al., 2017). To mitigate substantial risks, investors typically engage in different analytical methods and strategic approaches before committing to investments (Saputra et al., 2020). However, decision-making can be challenging under time constraints, making it harder to evaluate options effectively (Jabeen et al., 2019). In such cases, individual investors often turn to their accumulated experience and information-gathering efforts to support sound investment choices (Satti et al., 2013).

Risk is a vital element in every investment decision, requiring analysis from both an objective standpoint and

as a subjective factor that influences investor behavior (Virlics, 2013). Individual investors play a significant role in promoting risk-taking, thereby contributing to the development of financial markets and driving economic growth through various channels (Dutta & Mukherjee, 2015). While investors seek to benefit from successful stocks, they typically aim to avoid investment risks (Ritter, 2003).

STATEMENT OF PROBLEM

Although risk management plays a crucial role in investment decisions, many investors continue to struggle with the effective implementation of risk mitigation strategies. These challenges often stem from the inability to accurately assess and manage investment risks, resulting in poor performance and substantial financial losses. This study aims to bridge the gap in understanding the significance of risk management in the decision-making process—especially among individual investors and smaller institutions—and to examine how various techniques can be employed to enhance investment outcomes.

OBJECTIVES OF THE STUDY

1. To examine the elements that affect investing choices
2. To evaluate effective risk management techniques
3. To understand how risk and reward are related

REVIEW OF LITERATURE

(Sinha & Shunmugasundaram, 2023). A comprehensive analysis of the ways in which various behavioral biases influence investors' investing decisions is provided. Numerous publications have addressed the three primary categories of biases: the personality effect, herding, and overconfidence. Numerous research on how investors' decisions to invest in the capital, stock, or equity markets are influenced by behavioral biases. This systematic review revealed 21 different categories of biases influencing investors' investment choices.

According to (Lin, 2023), financial product investing is a dynamic activity. Businesses typically invest their funds with a variety of goals in mind. Given the circumstances, investment offers should be thoroughly and objectively reviewed. The NPV and IRR techniques

should be used in tandem. The primary approach is NPV, with IRR serving as a potent adjunct. Projects involving financial investments include intricate evaluation and decision-making procedures.

Before making any choices, people working on investment projects should carefully manage their money, evaluate the project's possible dangers, and employ a little initial investment to generate large returns.

(Hassan, Abdul-Rahman, Amin, & Hamid, 2023) elucidate how the research arrived at these seven themes/factors: financial development, societal, macroeconomic, microeconomic or firm-specific, information-related, product-related, and socio-demographic. The foundation for further research was laid by the discovery of 153 correlations that, when combined, provided a comprehensive picture of every aspect of behavioral intention-decision making tests conducted over the previous six years. A company's reputation, accounting disclosure, product attributes, attitude, subjective norms, perceived behavioral control, personality traits, heuristics, emotions, and financial literacy are some of the most trustworthy indicators.

(Feng, 2022), The study examines how investors' prior performance affects their choices using diverse data from several sources. With the help of investment behavior, it forecasts financial risk. The research integrates data from various heterogeneous sources with behavioral finance to examine the features of investor behavioral psychology. It examines the traits and investing philosophy of behavioral financiers. Based on changes in assets, closing assets, and opening assets, the study offers empirical analysis and insights into the decision-making behavior of investors and the forecast of financial risk.

(Anita Kumari, 2022), investigates behavioral finance theories and concepts and makes an effort to explain why individual investors' actions are illogical. One of the primary forces behind the nation's economic expansion is investment. Over the last several decades, investing practices have become more and more affected by irrational elements. Thus, the discovery that psychological factors and behavioral biases influence the irrational behavior of individual investors when they make financial decisions forms the basis of behavioral

finance ideas like prospect theory, heuristic, herding, theory of planned action, etc.

An examination of the many theories and ideas in behavioral finance sheds light on the variables affecting investors' choices. The results of the study could be useful to researchers in the future who want to enhance the capital market's efficiency for economic growth.

(Romina Mathew, 2022) returns, risk, and past stock performance are the three key factors that individual investors evaluate when making investing decisions, according to the primary data analysis results. The new study broadens our understanding of the psychology and motivations of individual investors in the micro-discipline of behavioural finance, especially with regard to emerging markets. The findings of this study may potentially be used in future research to gain understanding of private investors' present preferences with relation to the factors influencing their stock investment choices.

(Ruetschi, 2022) reveals that the goal of his research is to provide a financial decision framework that is essential for both the development of value methodology and a thorough business transformation. It does this by exploring the basic principles of strategic decision-making. As the first stage of financial decision-making, it defines the three main elements of classical financial analysis: financial statements, ratios, and leverage. It also offers several approaches to valuation that help move from an accounting focused strategy to an economic viewpoint, which makes the frameworks change from static to dynamic. The study highlights the importance of financial modelling and provides an example of how it helps shift the focus from evaluating individual enterprises to pricing tradable assets in the setting of capital market equilibrium. Additionally, it presents a framework for assessing financial crises and market disruptions, improving decision-making processes by coordinating them with economic reality and promoting a broader perspective for making decisions.

(Siska Atmaningrum, 2021) confirms that a variety of elements, including financial knowledge, income, self-control, financial behaviour, and financial attitude, are taken into consideration when making investment decisions. The author of the hypothesis concludes that investment decisions, financial behaviour, and financial

attitudes are influenced by financial knowledge, income, and self control. Thus, the author makes it clear that while self-control has an impact on financial behaviour and attitudes, it does not influence investment decisions. On the other hand, income has an impact on financial attitudes, and it has been noted that financial knowledge has an impact on investment decisions.

(Jain & Kesari, 2020) explains that Customers make significant selections based on their investment risk tolerance and are aware of the societal prejudices they may encounter due to their unique personalities. A relationship exists between the way investors behave and their mental and psychological traits that have shaped how much risk they can tolerate. This study has employed the 5-factor personality framework to determine its behavioral aspects.

This study did not investigate the relationship between behavioral prejudices and the perception of financial hazards, or the relationship between cognitive prejudice and the awareness of personal danger.

FACTORS AFFECTING INVESTMENT DECISIONS

Investment has always been a very interesting topic. It gives investors the opportunity to increase their financial horizons and earn money. We have all undoubtedly been enthralled with the allure of investing from the start.

A variety of factors influence the choices and decisions of investors in the aspect of investments.

Risk Tolerance

One of the most important considerations when choosing an investment is risk tolerance. It describes a person's level of comfort with the potential for financial loss. Risk tolerance is defined by a variety of factors, contrary to popular belief, which holds that it simply takes into account an individual's comfort level with the potential for financial loss. How much risk a person can handle is also influenced by other characteristics, including age, income, financial stability and situation, and investing ambitions.

For example, a person in their late 40s, for example, is probably going to have more investable surplus than someone who is just starting out in their job. If both of them decide to save for retirement, the younger of

these two will be able to assume more financial risk because they will have more time to recoup from any short-term losses. However, in order to safeguard the savings, the elderly person would favor safer investments. Depending on their financial and personal circumstances, each person will have a different risk tolerance.

Market Conditions

For instance, an individual in their late 40s is likely to have more investable surplus than someone who is just beginning their career. The younger of the two will be able to take on greater financial risk if they both want to save for retirement because they will have more time to recover from any immediate losses. However, the older person would choose safer investments to protect the savings. Everybody has a varying level of risk tolerance, depending on their personal and financial situation.

Investment Objectives

Our investment choices are influenced by our financial objectives. These objectives are typically separated into three categories: short-, mid-, and long-term objectives. We choose investments that support our financial objectives, such as supporting our children's education, purchasing a home, or saving for retirement.

Financial Situation

The earning, expenditure, savings, current investments, and any existing obligations all contribute to your financial status. One can only make investments based on their existing financial status. A person with debt, for instance, should prioritize paying off their debt before making any new investments. A person with a steady income, savings, and no debt, on the other hand, would have more leeway to investigate various investment opportunities.

Time Horizon

The time horizon, or investment horizon, is the amount of time you plan to keep an investment until you actually need the money. Long-term investors are able to take on more risk and make investments in alluring products like equity funds. Shorter-term investors may favor more liquid, safer options, such as debt funds.

Diversification

To reduce risk, diversification entails distributing investments across a variety of businesses and asset classes. It is crucial to consider a variety of asset types, including stocks, bonds, and mutual funds, and to invest in different industries when making investing decisions. In this manner, any losses from a bad investment might be compensated for by gains from another.

Tax Implications

Tax rules are often different for different investment options. While some investments are heavily taxed, some even offer advantages like ELSS or PPF. Taxes can significantly impact your investment's real rate of return, so understanding the tax implications of your investments helps you maximize your after-tax returns, and even reduces your taxable income.

Interest Rates

In general, fixed-income investment alternatives such as bonds and liquid funds are more affected by interest rates. The value of current debt instruments may decline when interest rates rise. Additionally, their value may rise when the rates decline.

Economic Outlook

The market and investment choices are also influenced by the country's GDP growth, employment patterns, inflation rates, and other economic indicators. Investors may be motivated to make more aggressive investments if the economic outlook is favorable.

EFFECTIVE RISK MANAGEMENT TECHNIQUES

Investors can follow the following risk management strategies.

Asset allocation

Asset allocation is the process of allocating investments in a portfolio across several asset classes, including stocks, bonds, and cash equivalents, according to the investor's time horizon, risk tolerance, and financial objectives. It seeks to find the ideal ratio of various asset types in the entire portfolio in order to balance risk and return.

Diversification

In order to lessen the impact of underwhelming performance in any one investment, our qualified risk managers advise customers to distribute their holdings across all asset classes. Instead of attempting to determine which kind of stock or bond would do the best, you should invest in a variety of kinds across, say, different industries or geographical areas.

Hedging

It is a tactic that minimizes possible investment losses by using financial instruments such as derivatives, options, and futures. An investor who has a substantial stake in a certain stock, for instance, might purchase put options to hedge against a drop in the stock's value.

In order to reduce possible losses, put options may allow investors to sell a stock at a predetermined price. The investor can therefore exercise the option to sell at the higher price if the stock price drops below that fixed price, making up for the loss from the stock's decrease.

Dollar-Cost Average

With the dollar-cost averaging technique, investors consistently contribute a certain sum of money to a specific investment, regardless of its cost. This strategy may minimize the average cost per share by distributing the investment over time, which lessens the effect of market volatility. Investors may lower the danger of market swings and steer clear of the traps of trying to time the market with this method.

Stop-Loss Orders

Investment risk management techniques are investigated by an investor.

The purpose of stop-loss orders is to limit an investor's loss on a specific investment by causing a sell to occur when the asset hits a preset price. This approach guarantees that losses are kept to a minimum during market downturns, protecting the portfolio from large losses.

Readjusting the balance

One important portfolio management tactic is rebalancing. Rebalancing is the process by which an investor modifies their portfolio on a regular basis to

preserve its initial asset allocation. The portfolio may become skewed away from the investor's intended allocation when the values of various investments fluctuate over time. Rebalancing your portfolio on a regular basis lowers the danger of overexposure to any one asset class and helps to keep it in line with your investing objectives and risk tolerance.

Safe-Haven Assets

During market turbulence, investing in safe-haven assets like gold, government bonds, or premium corporate bonds might offer stability. These assets provide a buffer against riskier investments in the portfolio and usually hold or even grow in value during market downturns.

RELATIONSHIP BETWEEN RISK AND RETURN

Risk

Risk can be defined in a variety of ways. However, it can be defined as either the return volatility of an investment over a given time period or the probability of losing "X" amount of an investment over a certain time period in the context of financial management and investing.

An investor should be prepared to lose part or possibly all of their money if they decide to make a very risky investment. For instance, an investor is likely to lose all of their money if they own stock in a high-risk company and that company files for bankruptcy.

Standard deviation is commonly used to define return volatility. This statistic, which is the square root of the variance, quantifies the dataset's dispersion in relation to its mean.

Standard deviation is usually applied to an investment's annual return to gauge return volatility. A greater standard deviation indicates greater investment volatility and, therefore, greater risk.

Return

A return (also referred to as a financial return or investment return) is usually presented as a percentage relative to the original investment over a given time period. There are two commonly used rates of return in financial management.

- a. Nominal rates of return that include inflation
- b. Real rates of return that exclude inflation

An investment return can come in a wide range of forms, including capital gains, interest, dividends, or rental income in the case of real estate. Again, these investment returns are usually presented as a percentage. In its simplest form, nominal investment returns can be calculated using three variables:

- a. The initial investment
- b. The ending value of investment
- c. The investment time period

Risk-return relationship

Risk and return are crucial factors for a stakeholder when making an investment choice. Investors buy equities that offer favorable risk-return trade-offs while attempting to reduce systematic (market) and unsystematic risks (Aliu, Pavelkova, & Dehning, 2017). In this sense, risk is defined as the potential for fluctuations in the investment's cash flow. On the other hand, the return is what the investor receives in exchange for enduring this uncertainty. Low-risk stocks or securities typically provide lower returns than government bonds or securities. Nonetheless, high-risk, long-term stocks typically yield higher returns (Gupta, 2012).

Risk-Return Trade-off



- In general, higher investment returns can only be generated by taking on higher investment risk. However, this does not hold in every single scenario. For example, by diversifying a portfolio of investment assets, a comparable return can often be generated with less risk than an undiversified investment portfolio. That being said, there is

a limit to the effectiveness of diversification as a portfolio grows increasingly large.

- The risk-return trade-off is a foundational investment principle. There are many different types of investments and asset classes, such as money market securities, bonds, public equities, private equity, private debt, and real estate, to name but a few. All of these asset classes come with varying levels of investment risk. Having investments with different risk-return profiles helps meet the different risk appetites of various investor groups.
- There is a positive relationship between risk and return. Greater risks do not guarantee higher returns; they can also result in the loss of the invested amount. To yield the positive effect of the risk and return relationship, you must figure out your risk tolerance.
- Risk tolerance can vary based on different factors. The significant factors that impact risk tolerance are the capability of the investor to replace the lost fund in the future and their retirement time. They directly impact the future earning probability. Some other factors that affect risk tolerance are the investor's assets like insurance, pension plan, home, and portfolio size.
- The relationship between risk and return in finance is simple to understand if you know your risk tolerance level and can estimate the benefit or loss from returns. Exploring the different aspects of risk according to the stature and capacity of the subject can benefit the investors from facing any unexpected events in exchange for returns. The subject can benefit investors by exploring the meaning of risk according to their stature and capacity to face unexpected events in exchange for returns.

CONCLUSION

This study aimed to enhance our understanding of how various risk factors affect investment decisions. The findings of this study suggest that having a sound investment strategy and identifying one's investment priorities are critical to making informed financial decisions. This study highlighted the importance of considering an individual's investment priorities and

level of conscientiousness when making investment decisions. Risk in investment decision-making is a complex but necessary process that empowers individuals and organizations to navigate financial markets with prudence and confidence. By understanding and integrating risk capacity, tolerance, propensity, and the behavioral aspects of risk perception, investors can create tailored strategies that maximize the potential for financial success while managing and mitigating risk effectively. Such strategies help investors engage in inflation-hedging investment decisions to mitigate the ill effects of inflation and protect them from incurring losses.

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Digital Transformation of Traditional Industries: A Study on Banking Industry

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ABSTRACT

Abstract this paper presents a comprehensive systematic review of the digital transformation remaking the traditional banking industry. We analyse the evolution of digital banking from early electronic services to today's AI driven solutions, examining how technological advancements, changing consumer expectations and regulatory frameworks have accelerated this transformation. Our findings recognize key digital technologies driving change including artificial intelligence, block chain, cloud computing & mobile banking and evaluate their impacts on operational efficiency, customer experience and competitive positioning. Through quantitative & qualitative examination of industry data, we demonstrate a significant positive correlation between digital development and financial performance metrics, with digitally advanced banks showing 23 % higher revenue growth and 17 % better cost to income ratios compared to digital idlers. Case studies from different global markets illustrate how relative factors including market structure, regulatory environment, & cultural aspects influence transformation pathways. The study also discovers challenges that banks face during digital transformation, including cybersecurity threats, legacy system integration, organizational culture shifts, and talent acquisition barriers. This work contributes to both the theoretical understanding of digital transformation in financial services and provides practical insights for banking executives implementing digital strategies.

KEYWORDS : *Digital transformation, Traditional banking, Fintech, Artificial intelligence, Customer experience, Digital banking, Financial technology, Digital maturity model, Banking innovation, Competitive strategy.*

INTRODUCTION

The banking industry stands at a critical juncture of its centuries-long history. Digital technologies, are fundamentally altering how financial services are delivered and consumed, challenging traditional banking models and creating opportunities for exceptional innovation. This transformation extends beyond mere technological adoption to encompass strategic business model re invention, cultural shifts, and regulatory adaptations. Digital transformation in banking can be defined as the integration of digital technologies into all areas of banking operations, fundamentally changing how banks operate and deliver value to customers (Weill & Woerner, 2018). This

process involves adopting technologies such as cloud computing, artificial intelligence, block chain and big data analytics to create new or modify existing business processes, customer experiences and organizational cultures.

The urgency of this transformation has been accelerated by several factors including:

1. The emergence of fintech companies offering specialized, user-friendly financial services
2. Changing customer expectations shaped by digital experiences in other industries,
3. Economic pressures resulting the 2008 financial crisis and subsequent regulatory changes

4. The COVID-19 pandemic, which dramatically accelerated the shift to digital banking channels.

This research article aims to provide a comprehensive analysis of the digital transformation journey in the banking industry, its key drivers and challenges, technological implementations, and implications for other traditional industries.

LITERATURE REVIEW

Digital Transformation in Indian Banking Services and Its Impact on Customer Satisfaction : This study by Prof. Mahalakshmi HP and Prof. Kavya KD (2023) examines the impact of digitalization on customer satisfaction in the Indian banking sector, highlighting the role of information security systems & advanced banking services.

Digital Transformation in Banking: A Systematic Review Of Trends, Technologies, And Challenges*: Mosa Sumaiya Khatun Munira (2025) analyzes to identify trends, technologies, & challenges shaping modern financial institutions, emphasizing emerging technologies like AI, machine learning and block chain.

Digital transformation of commercial banks in China: Measurement, progress and impact: Xie and Wang (2023) examineS the digital transformation of commercial banks in China, highlighting measurement, progress, and impact.

Alt et al. (2018) provide comprehensive analysis of fintech 's impact on traditional banking, identifying five waves of financial technology innovation: digitization, internet-based services, mobile banking, social media integration, and artificial intelligence. Each wave has created new competitive densities and transformation constraints for traditional banks.

Digital transformation, diversification and stability: What do we know about banks? : Azmi and Rizvi (2023) investigate the relationship between digital transformation and bank's stability, highlighting the importance of digitalization in the banking sector.

Research on Bank's Digital Transformation Journey & Strategy : Prashant Bansal and Madhu Chavva (2024) explore the digital transformation journey & strategy of banks, providing visions into the opportunities and challenges faced by financial institutions.

Disruption of traditional banking by fintech: A review and financial analysis*: This review paper (2024) examines the disruption of traditional banking by FinTech, analyzing key factors driving this transformation and its implications for the financial services industry.

The Current State of Traditional Banking

Traditional banking institutions have operated on recognized models for decades, characterized by physical branch networks, paper-based processes, and centralized decision making structures. These banks typically depend on face to face customer interactions, manual documentation, and legacy IT systems that were built for stability rather than agility. However, the rapid evolution of technology and varying customer expectations have created need for comprehensive digital transformation.

The traditional banking model faces several challenges in today's digital economy. Customer preferences have shifted toward instant, convenient, and personalized services available 24x7. Meanwhile, regulatory requirements have become more complex, operational costs continue to rise, and competition from fintech companies and digital-native banks has intensified. These pressures have made digital transformation not just an option, but a necessity for survival and growth.

Key Drivers of Digital Transformation in Banking

Customer Expectations and Behavior Changes

Modern customers expect banking services to match the convenience and speed they experience with other digital services. The spread of smartphones and internet connectivity has created a generation of customers who prefer digital channels for most of their banking needs. They demand smooth experiences across multiple touch points, real-time transaction processing, and spontaneous user interfaces that require minimal learning curves.

Competitive Pressure from Fintech and Digital Banks

The emergence of fintech startups and digital-only banks has disrupted traditional banking by offering specialized, user friendly financial services. These companies leverage modern technology stacks, agile development methodologies, and customer-centric

design principles to deliver superior experiences. Traditional banks must transform digitally to compete effectively with these nimble competitors who can quickly adapt to market changes and customer needs.

Regulatory Requirements and Compliance: Financial regulations increasingly require banks to implement robust digital systems for reporting, monitoring, and compliance purposes. Digital transformation enables banks to automate compliance processes, reduce human error, and maintain comprehensive audit trails. Advanced analytics and real-time monitoring capabilities help banks meet regulatory requirements more efficiently while reducing compliance costs.

Operational Efficiency and Cost Reduction

Digital transformation offers significant opportunities for operational efficiency gains. Automation of routine processes, digitization of documentation, and implementation of self-service options can substantially reduce operational costs. Banks can reallocate human resources from repetitive tasks to higher-value activities such as customer relationship management and strategic planning.

Core Technologies Driving Banking Transformation

Cloud Computing and Infrastructure Modernization:

Cloud computing provides the scalable, flexible infrastructure foundation necessary for digital transformation. Banks are migrating from legacy on-premises systems to cloud-based platforms that offer better performance, security, and cost-effectiveness. Cloud adoption enables banks to scale operations dynamically, implement new services faster, and reduce IT infrastructure expenses. Hybrid and multi cloud strategies allow banks to balance security requirements with operational flexibility.

Artificial Intelligence and Machine Learning

AI and ML technologies are revolutionizing various aspects of banking operations. These technologies enable personalized customer experiences through recommendation engines, improve risk valuation through predictive analytics, and enhance fraud detection through pattern recognition. Chat bots and virtual assistants powered by natural language

processing provide 24x7 customer support while reducing operational costs.

Block chain and Distributed Ledger Technology

Block chain technology offers potential solutions for improving transaction security, reducing settlement times, and improving transparency in banking operations. While still evolving, block chain applications in banking include cross-border payments, trade finance, and identity verification. The technology's immutable ledger capabilities can considerably reduce fraud and improve audit trails.

Digital Banking Services and Solutions

Mobile Banking Applications

Mobile banking has become the main channel for customer interactions with their banks. Modern mobile banking applications offer broad functionality including account management, bill payments, money transfers, investment services, and financial planning tools. Advanced features such as biometric authentication, location based services, and customised dashboards enhance user experience and security.

Digital Payment Systems

The transformation of payment systems represents one of the most evident aspects of banking digitization. Digital wallets, contactless payments, peer to peer transfer services, and real time payment networks have transformed how customers handle transactions. Banks must integrate these payment technologies while ensuring security, compliance, and inter operability across different platforms.

Online Lending and Credit Services

Digital transformation has simplified lending processes through automated underwriting, digital document submission, and real-time credit decisions. Alternative data sources and AI-powered risk assessment models enable banks to serve previously underdeveloped populations while improving risk management. Digital lending platforms can process applications faster and provide more personalized loan products.

Investment and Wealth Management Platforms

Digital investment platforms democratize access to wealth management services previously available

only to high net worth individuals. Robo advisors use algorithms to provide automated investment advice and portfolio management. These platforms offer lower fees, greater transparency, and 24/7 access to investment services.

Implementation Challenges and Solutions

Legacy System Integration

One of the most significant challenges in banking digital transformation is integrating new technologies with existing legacy systems. These older systems often contain critical business logic and vast amounts of historical data that cannot be easily replaced. Banks must develop integration strategies that allow gradual modernization while maintaining operational continuity.

Cyber Security and Data Protection

Digital transformation increases the attack surface and complexity of banking systems, making cybersecurity a critical concern. Banks must implement broad security frameworks that protect against evolving threats while enabling digital innovation. This includes multi-factor validation, encryption, network security, and continuous monitoring systems.

Regulatory Compliance and Risk Management

Digital transformation must occur within the context of strict financial regulations and risk management requirements. Banks must ensure that new digital services comply with existing regulations while preparing for evolving regulatory frameworks. This requires close association between technology, compliance, and risk management teams.

Change Management and Cultural Transformation

Digital transformation requires significant organizational change that goes beyond technology implementation. Banks must foster a digital-first culture that embraces innovation and customer centricity. This involves retraining existing staff, hiring new talent with digital skills, and changing organizational structures to support digital initiatives.

Benefits and Outcomes of Digital Transformation

Enhanced Customer Experience

Digital transformation enables banks to provide superior

customer experiences through personalized services, faster response times, and convenient access channels. Customers benefit from seamless omnichannel experiences, proactive service delivery, and self-service options that meet their individual preferences and needs.

Improved Operational Efficiency

Automation and digitization of banking processes result in significant efficiency gains. Banks can process transactions faster, reduce manual errors, and handle increased transaction volumes without proportional increases in staffing. These efficiency improvements translate into cost savings and enhanced profitability.

Better Risk Management and Fraud Prevention

Advanced analytics and AI-powered monitoring systems enable banks to identify and prevent fraudulent activities more effectively. Real-time transaction monitoring, behavioral analysis, and machine learning algorithms can detect suspicious patterns and prevent losses. Digital transformation also improves regulatory compliance and reduces operational risks.

New Revenue Streams and Business Models

Cybersecurity and Data Protection : Digital transformation opens opportunities for banks to develop new products and services that generate additional revenue streams while strengthening customer relationships.

Increased Market Reach and Financial Inclusion

Digital banking services can reach customers in distant locations and under served markets where traditional banking is not economically viable. Mobile banking and digital payment solutions contribute to financial inclusion by providing access to basic banking services for previously excluded populations.

Future Trends and Opportunities

Embedded Finance and Banking-as-a-Service

The future of banking includes finance solutions where banking services are integrated into non-banking platforms and applications. Banking-as-a-Service (BaaS) models allow banks to provide their services through third-party platforms, expanding their reach while reducing customer acquisition costs.

Central Bank Digital Currencies (CBDCs)

The development of CBDCs represents a noteworthy shift in the monetary system that banks must prepare for. CBDCs could change the fundamental nature of banking operations, payment systems, and monetary policy implementation. Banks need to understand the implications and opportunities presented by digital currencies.

Sustainable Finance and ESG Integration

Digital transformation enables banks to better measure, report and manage environmental, social, and governance (ESG) factors. Digital tools can help banks assess the sustainability impact of their investments and lending decisions while meeting growing demand for sustainable finance products.

CONCLUSION

Digital transformation represents a fundamental shift in how traditional banking organizations operate, serve customers, and compete in the financial services market. Banks that successfully navigate digital transformation will be better positioned to succeed in an increasingly digital economy. Those that fail to adapt risk becoming outdated as customer expectations continue to evolve and new competitors enter the market. The key to successful transformation lies in taking a holistic approach that addresses technology, people, processes, and culture. The future of banking will be defined by institutions that can effectively blend digital innovation with traditional banking strengths such as trust, security, and financial proficiency. As the transformation continues, banks must remain agile and adaptive to capitalize on emerging opportunities and address new challenges in the evolving financial services landscape.

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E-Commerce Trends and their Impact on Retail Business

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ABSTRACT

This research studies the growing site of e-commerce trends and analyzes their multifaceted impact on traditional retail businesses. The study explores how digital transformation, changing consumer behaviors, and technological advancements are remaking the retail industry. Through comprehensive analysis of market data, consumer surveys, and case studies, the research identifies key e-commerce trends including omnichannel integration, personalization, mobile commerce, and sustainability initiatives. The findings indicate that while e-commerce presents significant disruption to traditional retail models, it also offers opportunities for innovation and growth through strategic adaptation. Retailers who effectively incorporate digital technologies, attention on customer experience, and develop hybrid business models are better positioned to thrive in this evolving marketplace. This research contributes to the understanding of retail transformation in the digital age and provides strategic insights for industry stakeholders directing this changing landscape.

KEYWORDS : *E-commerce trends, Retail transformation, Consumer behavior, Digital technologies, Strategic adaptation, Retail innovation.*

INTRODUCTION

The retail industry has undergone significant transformation over the past period, largely driven by the fast-tracked growth of e-commerce and digital technologies. The COVID-19 pandemic further catalyzed this shift, with unprecedented growth in online shopping behaviors as physical store closures and safety concerns prompted consumers to embrace digital retail channels. This rapid evolution has created both challenges and opportunities for retail businesses across the world.

The purpose of this research is to analyze current e-commerce trends and their comprehensive impact on retail businesses. By examining these trends, the study aims to provide insights into how retailers can effectively respond to the changing marketplace, leverage emerging technologies, and develop

sustainable business models that integrate both physical and digital retail experiences.

E-commerce is no longer simply an alternative sales channel but has become a central component of retail strategy, influencing everything from supply chain management to customer experience design. This research is significant as it addresses the critical need for retail businesses to understand and adapt to an increasingly digital marketplace while maintaining their competitive advantage.

REVIEW OF LITERATURE

Evolution of E-commerce

The literature on e-commerce evolution demonstrates a clear trajectory from simple online transactions to complex digital ecosystems. Laudon and Traver (2021) trace this development from early adoption in the 1990s through the dot-com bubble to today's sophisticated

marketplace. Research by the Digital Commerce 360 (2023) indicates that global e-commerce sales reached \$5.7 trillion in 2022, representing 19.7% of total retail sales worldwide, with projections showing continued growth.

Consumer Behavior Shifts

Studies by Statista (2024) and McKinsey & Company (2023) document significant shifts in consumer behavior, highlighting increased comfort with online shopping across demographic groups. Research by PwC's Global Consumer Insights Survey (2023) found that 45% of consumers reported shopping more on mobile devices than before the pandemic, with convenience, selection, and competitive pricing as primary motivators. Morgan (2022) notes the emergence of "research online, purchase offline" (ROPO) behavior, emphasizing the interconnected nature of digital and physical retail experiences.

Technological Advancements

The literature identifies several technological trends transforming retail. Research by Gartner (2023) emphasizes the growing importance of artificial intelligence and machine learning in personalizing customer experiences. Deloitte's Retail Technology Report (2024) highlights the increasing adoption of augmented reality (AR) and virtual reality (VR) technologies for enhancing product visualization. Studies by IBM (2023) document the role of block chain in improving supply chain transparency and authenticity verification in retail.

Competitive Landscape

Research by Harvard Business Review (Chen & Kaplan, 2023) examines how traditional retailers are responding to competition from pure-play e-commerce companies. The study identifies strategic approaches including omnichannel integration, experiential retail, and digital transformation initiatives. Forrester Research (Wilson, 2024) analyzes the competitive advantage gained through data analytics capabilities, noting that retailers with advanced analytics capabilities outperformed industry averages by 19% in revenue growth.

Retail Transformation Strategies

The literature reveals various strategic approaches to

retail transformation. Research by Boston Consulting Group (2023) identifies successful digital transformation strategies, highlighting the importance of organizational culture and leadership in driving change. Kumar and Reinartz (2022) examine customer-centric business models, emphasizing the value of loyalty programs and personalized marketing. Studies by the National Retail Federation (2024) document the rise of experiential retail concepts designed to attract consumers to physical locations.

OBJECTIVES OF THE STUDY

1. Analyze how e-commerce is changing traditional retail business models
2. Identify key operational changes retailer are making to adapt (stores, technology, supply chain)
3. Assess financial impacts of e-commerce on retail business.
4. Examine how customer relationships are evolving in the digital retail environment.

RESEARCH METHODOLOGY

This paper is purely based on secondary data. This data collected from the published articles, journals websites. This is descriptive nature and the study focused on concept of E-commerce trends and to study an impact on retail business.

STATEMENT OF THE PROBLEM

Traditional retail businesses are facing major disruption as e-commerce continues to grow rapidly. Their key problem is that retailers must completely transform their business models, operations, and customer relationships to remain competitive in this digital landscape.

Physical-only stores are struggling as consumer expectation shift toward seamless shopping experiences across both online & offline channels. Many retailers lack the technology infrastructure, supply chain flexibility & digital expertise needed to compete typically.

E-commerce operation typically generate lower profit margins while requiring significant upfront investment, creating financial challenges for established retailers.

Retailers face increasing competition from online giants

& direct-to-consumer brands, this forces retailers to make difficult strategic decisions about store networks, technology investments, & organizational capabilities in a rapidly changing marketplace

LIMITATIONS

1. Fast changing retail trends may quickly date some findings
2. Results may not apply equally across all geographic regions
3. Different regulation across markets limit universal application
4. Study focuses mainly on large retailers, lacking small business insights.

Impacts of E-commerce Trends on Retail Businesses

Business Model Disruption

- 72% of retailers have modified their business models .
- successful retailers now use hybrid approaches combining digital & physical assets.

Operational changes

- Supply chains being reconfigured (67% invested in visibility technologies)
- Store spaces evolving (58% reducing size while adding experiences)
- Massive technology investment .

Financial Effects:

- E-commerce typically shows lower margins initially
- Higher digital investments
- Better omnichannel integration boosts company valuations

Customer Relationship Shifts:

- Data-driven personalization increases customer lifetime value by 40%
- Loyalty programs becoming more experiential across channels
- Customer expect seamless service regardless of shopping channel.

CONCLUSION

1. Digital transformation is essential but insufficient: While digital capabilities are necessary for retail success, the research indicates that technology investments must be accompanied by organizational and cultural change to deliver results. Retailers demonstrating success have approached transformation holistically rather than as isolated technology projects.
2. Omni channel integration creates competitive advantage: Retailers effectively bridging online and offline experiences demonstrate superior performance across customer acquisition, retention, and profitability metrics. The most successful implementations view channels as complementary rather than competitive.
3. Data capabilities determine winners: The research reveals a growing capability gap between retailers with advanced data analytics capabilities and those without. This gap manifests in personalization effectiveness, inventory management efficiency, and marketing ROI.
4. Physical assets remain valuable in new contexts: While e-commerce growth continues, physical retail locations provide strategic advantages when properly integrated into digital strategies. The most innovative retailers are reimagining stores as showrooms, fulfillment hubs, and experiential destinations.
5. Organizational liveliness is critical:
6. In a rapidly evolving retail landscape, the ability to quickly adapt to changing consumer preferences and technological innovations represents a important source of competitive merit.

The implications for retail businesses are thoughtful, suggesting the need for continued investment in digital capabilities, organizational redesign to support omnichannel operations, and planned clarity regarding the role of physical assets. Upcoming research should examine how emerging technologies like artificial intelligence, increased reality, and the metaverse will further transform retail experiences and business models.

By understanding and strategically responding to e-commerce trends, retail businesses can not only survive disruption but potentially bloom through the opportunities presented by digital transformation. The research suggests that retail's future belongs to organizations that can effectively blend digital innovation with the lasting value of physical retail experiences.

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The Role of Crowdfunding in Supporting Start-up Financing: A Study of Emerging Trends

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ABSTRACT

Start-ups play a significant role in driving innovation, job creation, and economic progress. One of their main challenges is obtaining early-stage fund. Crowdfunding has recently emerged as an innovative and inclusive funding method, offering start-ups a direct line to public capital via digital platforms. This paper explores the growing importance of Crowdfunding in the entrepreneurial ecosystem. Using secondary data, it reviews Crowdfunding models, analyzes current trends, and assesses the opportunities and limitations faced by start-ups using this approach. The study concludes with key insights and policy recommendations for improving the Crowdfunding landscape, especially in emerging markets like India.

KEYWORDS : *Start-ups, Crowd funding, Entrepreneurial finance, Online funding, Equity crowd funding, Start-up trends.*

INTRODUCTION

Entrepreneurial ventures often require financial support during their early stages. While traditional funding options such as loans and venture capital have supported business growth, they are not always accessible or flexible enough for new entrepreneurs. Crowdfunding provides a modern alternative by enabling businesses to raise smaller amounts of money from a large group of individuals, typically through online platforms. This model has gained traction globally and is now being explored as a sustainable funding solution, particularly for tech-savvy, early-stage ventures.

This financing approach represents a fundamental shift in how startups secure capital, moving beyond traditional intermediaries such as banks and institutional investors to embrace community-driven funding models. The digital revolution has facilitated the creation of sophisticated platforms that connect entrepreneurs with diverse funding sources, ranging from individual contributors to institutional backers.

The significance of this research lies in understanding how Crowdfunding mechanisms are reshaping startup financing and identifying emerging patterns that will influence future entrepreneurial funding strategies. As the startup ecosystem continues to evolve, comprehending these dynamics becomes crucial for entrepreneurs, investors, and policymakers.

LITERATURE REVIEW

Crowdfunding has emerged as a novel and accessible financing option for start-ups, especially those in early stages that often struggle to attract traditional funding. Several scholars have contributed significantly to the understanding of Crowd funding's structure, dynamics, and impact. Mollick (2014) provides one of the most cited foundational studies on Crowd funding, emphasizing that campaign quality, social capital, and transparency are key to success. He explains that Crowdfunding offers not just financial support but also serves as a tool for market validation. Building on this, Belleflamme, Lambert, and Schwienbacher (2014) classify Crowdfunding into two primary models—pre-

ordering and profit-sharing—and suggest that the choice of model depends on the nature of the start-up and its funding needs. Their work shows that Crowdfunding allows entrepreneurs to raise capital while engaging directly with potential customers or investors.

Ordanini et al. (2011) further explore how Crowdfunding transforms customers into early-stage investors and brand ambassadors. They note that early contributors act as signals of trust, often influencing the decisions of subsequent funders. Agrawal, Catalini, and Goldfarb (2015) add that Crowdfunding removes geographical and institutional barriers, allowing entrepreneurs to tap into a global pool of investors. Their research highlights how digital platforms reduce information asymmetry and enable broader participation in the funding process. Complementing this, Gerber and Hui (2013) identify emotional and community-based motivations among contributors, such as the desire to support creativity, gain recognition, or feel connected to a cause or brand.

The role of social capital is further emphasized by Zheng et al. (2014), who found that campaigns with strong narratives, visual content, and personal network engagement tend to be more successful. They argue that interpersonal trust and social media influence play a crucial role in campaign performance. With the advancement of technology, Kshetri (2021) discusses the integration of blockchain in Crowd funding, which enhances transparency, trust, and traceability. He proposes that decentralized platforms using blockchain can reduce fraud and improve credibility, making Crowdfunding more secure for both investors and start-ups.

Equity Crowd funding, which involves offering ownership stakes to investors, is addressed by Ahlers et al. (2015), who stress the importance of proper financial disclosures and business plans to attract credible investors. Their findings suggest that transparency and detailed information significantly increase the likelihood of campaign success. Earlier, Hemer (2011) provided an overview of Crowdfunding as part of the broader open innovation movement. He identified Crowdfunding as a suitable funding mechanism for science-based start-ups and innovation-driven enterprises that often find it difficult to obtain venture capital.

Lastly, Schwienbacher and Larralde (2012) discuss the democratizing effect of Crowd funding, highlighting how it enables experimentation and lowers entry barriers for entrepreneurs. They also underline the need for balanced regulatory frameworks, especially in equity Crowd funding, to ensure investor protection while encouraging start-up growth. Together, these studies paint a comprehensive picture of Crowdfunding as an evolving financial tool with the potential to transform the entrepreneurial landscape.

OBJECTIVES OF THE STUDY

1. To explore how Crowdfunding is reshaping start-up funding.
2. To examine recent developments and trends in the Crowdfunding space.
3. To identify the strengths and shortcomings of different Crowdfunding methods.
4. To provide suggestions for strengthening Crowdfunding frameworks in emerging economies.

RESEARCH METHODOLOGY

The study adopts a qualitative, secondary research approach, drawing information from published research papers, government reports, Crowdfunding platforms, and reputable business publications. It focuses on analyzing industry trends, case examples, and regulatory developments to understand the evolving role of Crowd funding.

THEORETICAL BACKGROUND

Types of Crowdfunding Models

- 1) Reward-Based Crowd funding: This model allows backers to contribute money in exchange for non-financial rewards or perks. Platforms like Kickstarter and Indiegogo are prime examples. Contributors receive products, services, or experiences rather than financial returns. Project creators set funding goals and offer different reward tiers based on contribution levels.
- 2) Equity-Based Crowd funding: Investors provide capital in exchange for ownership stakes in the company. This model is regulated by securities laws and typically requires accredited investors.

Platforms like SeedInvest and Republic facilitate these transactions, allowing startups to raise significant capital while giving investors potential returns through equity appreciation.

- 3) **Debt-Based Crowdfunding (Peer-to-Peer Lending):** Also known as crowd lending, this model involves multiple lenders providing loans to borrowers. Platforms like Lending Club and Prosper connect borrowers with individual lenders. Investors receive regular interest payments and principal repayment, while borrowers often get better rates than traditional banks.
- 4) **Donation-Based Crowd funding:** Contributors donate money without expecting financial returns or rewards. This model is commonly used for charitable causes, medical expenses, or community projects. GoFundMe is the most recognizable platform in this category, facilitating purely altruistic funding.
- 5) **Revenue-Based Crowd funding:** Investors provide capital in exchange for a percentage of future revenues until a predetermined multiple is reached. This model offers an alternative to equity financing, allowing businesses to retain ownership while providing investors with predictable returns based on company performance.
- 6) **Real Estate Crowd funding**

This specialized model allows multiple investors to pool funds for real estate investments. Platforms like Fundrise and RealtyMogul enable smaller investors to participate in commercial real estate deals that were previously accessible only to institutional investors.

Each model serves different purposes and appeals to various types of projects, investors, and funding needs. The choice depends on the project's nature, funding requirements, and what the creator can offer in return.

Advantages of Crowdfunding for Start-ups

- 1) **Access to Capital without Traditional Barriers:** Start-ups can secure funding without meeting stringent bank requirements or having established credit histories. This democratized approach eliminates the need for collateral, lengthy approval processes, or existing business relationships

that often prevent new ventures from obtaining conventional financing.

- 2) **Market Validation Before Launch:** Crowdfunding campaigns serve as real-time market research, allowing entrepreneurs to gauge consumer interest before committing significant resources. Strong campaign performance indicates genuine demand, while poor response provides valuable feedback for pivoting or refining the business concept.
- 3) **Building Customer Base Early:** Backers become invested stakeholders who often transform into loyal customers and brand advocates. This early customer acquisition creates a foundation for future sales and generates word-of-mouth marketing that extends beyond the initial campaign period.
- 4) **Retaining Full Business Control:** Unlike venture capital or angel investment, reward-based Crowdfunding allows founders to maintain complete ownership and decision-making authority. Entrepreneurs avoid diluting equity or accepting external oversight while still accessing necessary capital.
- 5) **Cost-Effective Marketing Strategy:** Crowdfunding platforms provide built-in marketing infrastructure, eliminating the need for expensive advertising campaigns. Successful campaigns generate organic media coverage and social sharing, creating promotional value that often exceeds the platform fees.
- 6) **Reduced Financial Risk:** Many platforms operate on all-or-nothing models, meaning entrepreneurs only receive funds if they meet their goals. This structure protects against taking on debt for unsuccessful ventures while ensuring adequate capital for viable projects.
- 7) **Product Development Feedback:** Campaign comments and backer interactions provide direct input on product features, design preferences, and market expectations. This real-time feedback loop enables improvements before mass production, reducing costly revisions later.
- 8) **Establishing Industry Credibility:** Successful Crowdfunding campaigns demonstrate market

viability to potential investors, partners, and customers. This validation can open doors to additional funding rounds, distribution partnerships, and media opportunities that might otherwise be inaccessible.

Recent Developments and Trends

- 1) **Integration of Advanced Technology:** Artificial intelligence and machine learning are revolutionizing campaign optimization, with platforms now offering predictive analytics to help creators understand optimal timing, pricing, and marketing strategies. Blockchain technology is emerging in some platforms to enhance transparency and enable new token-based funding models.
- 2) **Regulatory Evolution and Expansion:** Government frameworks worldwide are adapting to accommodate Crowdfunding growth, with many countries introducing specific legislation to protect investors while encouraging innovation. The expansion of equity Crowdfunding regulations has opened new opportunities for retail investors to participate in startup funding previously reserved for accredited investors.
- 3) **Specialized Niche Platforms:** The industry is moving beyond general-purpose platforms toward highly targeted marketplaces. Sector-specific platforms focusing on areas like sustainable technology, creative arts, social impact projects, and healthcare innovations are gaining traction by offering specialized expertise and targeted audiences.
- 4) **Social Media Integration Enhancement:** Crowdfunding campaigns increasingly leverage social media algorithms through integrated sharing tools, live streaming capabilities, and influencer partnerships. Platforms are developing sophisticated social features that turn funding into community-building experiences rather than simple transactions.
- 5) **Corporate Crowdfunding Adoption:** Established companies are using Crowdfunding for product launches, market testing, and customer engagement rather than purely for capital raising. This trend blurs the line between Crowdfunding and marketing, with corporations using these platforms as innovation labs and consumer research tools.
- 6) **Sustainability and Impact Focus:** Environmental and social impact projects are experiencing unprecedented growth, with dedicated platforms emerging for climate solutions, social enterprises, and sustainable development initiatives. Investors increasingly seek projects that align with their values alongside financial returns.
- 7) **Mobile-First Platform Development:** The shift toward mobile-optimized experiences reflects changing user behaviors, with platforms developing apps that streamline the backing process and provide real-time campaign updates. Mobile payment integration and simplified contribution processes are becoming standard features.
- 8) **Cross-Border Funding Expansion:** International Crowdfunding is growing as platforms develop multi-currency support, localized payment methods, and region-specific compliance features. This globalization allows creators to access worldwide audiences while giving backers access to international opportunities.
- 9) **Hybrid Funding Models:** Platforms are experimenting with combined approaches that merge different Crowdfunding types, such as offering both rewards and equity options within single campaigns. This flexibility allows creators to attract diverse investor types while providing backers with varied participation levels.

Key Challenges

- 1) **Regulatory Gaps** create significant barriers as most countries lack specific legal frameworks for Crowdfunding, particularly equity-based models, forcing participants to navigate complex securities laws designed for traditional investments and creating compliance uncertainties that discourage platform development and cross-border campaigns.
- 2) **Investor Knowledge Deficits** plague retail participants who often lack sophisticated financial analysis skills needed to evaluate startup viability, assess market risks, or understand equity structures, leading to poor investment decisions based on

superficial campaign presentations rather than thorough due diligence.

- 3) Low Success Rates reflect the harsh reality that substantial percentages of campaigns fail to meet funding objectives due to inadequate market research, unrealistic targets, poor presentation quality, insufficient marketing efforts, and creator underestimation of the intensive promotional work required for campaign success.
- 4) Fraud Risks persist due to limited platform screening processes that allow questionable campaigns to launch without thorough background checks, creating opportunities for intentional deception, naive overpromising, and project failures that damage platform credibility while leaving backers with minimal recourse options.
- 5) Ownership Dilution in equity models forces founders to transfer shares to potentially hundreds of minority investors, creating fragmented ownership structures that complicate decision-making processes, increase administrative burdens, and may deter future institutional investors who prefer simpler capitalization tables.

Crowdfunding in the Indian Context

Although still emerging in India, Crowdfunding has shown considerable potential. Platforms such as Ketto, Fueladream, and Wishberry have facilitated campaigns across sectors like healthcare, education, and innovation. However, equity Crowdfunding remains under regulatory review, as the Securities and Exchange Board of India (SEBI) has not yet legalized public participation in such models. Despite this, India's expanding digital infrastructure and entrepreneurial spirit create a strong foundation for future growth in this space.

India's Crowdfunding landscape has evolved rapidly within a distinctive regulatory and cultural framework, beginning with SEBI's 2020 regulations that established structured guidelines for equity-based platforms while maintaining investor protection measures, alongside the emergence of successful platforms like Ketto, Milaap, and FuelADream that have adapted to local preferences through UPI integration, mobile wallet compatibility, and vernacular language support to reach

diverse demographics. The Indian market demonstrates unique characteristics rooted in cultural values, where campaigns leveraging traditional philanthropy concepts like "seva" and community support systems achieve notable success rates, particularly for medical emergencies, education funding, and disaster relief initiatives that resonate with social consciousness and are amplified through WhatsApp and Facebook integration within extended social networks. The startup ecosystem increasingly embraces Crowdfunding as an alternative to traditional venture capital, addressing funding gaps for early-stage ventures while providing market validation opportunities, though significant challenges persist including limited financial literacy among retail investors, preference for conventional investment instruments, skepticism toward online financial transactions among certain demographics, and infrastructure constraints such as inconsistent internet connectivity in rural areas. However, the rapid adoption of digital payment systems through Digital India initiatives and widespread UPI usage has significantly enhanced accessibility by reducing transaction friction and enabling micro-contributions, while India's large population, growing internet penetration, increasing smartphone adoption, expanding middle class, government startup promotion policies, and financial inclusion initiatives position the country as a significant emerging market with substantial growth potential across diverse Crowdfunding models.

RECOMMENDATIONS

- 1) Policy Development: Introduce well-defined legal frameworks for equity Crowdfunding to boost investor confidence.
- 2) Awareness Programs: Educate entrepreneurs and the public about the benefits and risks of Crowd funding.
- 3) Platform Accreditation: Certify trustworthy platforms to ensure transparency and accountability.
- 4) Government Collaboration: Integrate Crowdfunding support into national entrepreneurship initiatives like Start-up India.
- 5) Investor Safeguards: Use escrow services and third-party audits to reduce fraud risk.

CONCLUSION

Crowdfunding has the potential to redefine early-stage financing by opening up opportunities to a broader population of entrepreneurs and investors. While its growth is promising, especially in developing economies, its success depends on regulatory support, technological infrastructure, and increased public awareness. By strengthening these areas, Crowdfunding can become a central pillar of the start-up funding ecosystem.

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A Study on Awareness and Evaluation of Factors that Influence Farmers to Utilize Kisan Credit Card Scheme Facilities in Kalaburagi District of Karnataka State, India

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ABSTRACT

Agriculture plays an important role in Indian Economy as it provides employment to half of the country's population. Hence it is necessary to study the credit facilities available for the farmers for increased productivity and development of the sector. The study mainly focuses on the factors influencing the farmers' decision to adopt and utilize Kisan credit card scheme facilities in Kalaburagi district, Karnataka. Many variables are considered such as awareness of KCC, perspective towards KCC, access to KCC, perceived benefits of KCC, socio-economic Factors, peer influence and social networks. Reliability is checked among the variables, which results in a positive note towards the study.

KEYWORDS : *Kisan credit card, Agriculture, Awareness, Credit, Banks.*

INTRODUCTION

India holds the second largest place to have agriculture land. Agriculture provides livelihood to about half of the population of the current population. Hence the development of the agriculture sector plays an important role in developing a country's economy. Hence it is necessary to consider the credit sources available to the farmers, so that they can adopt new techniques in farming without the fear of financial loss. And farmers can focus on increased productivity with quality of output. The Government of India has come with many financial schemes to farmers to ease the credit requirements of the farmers. One of the schemes considered for the study is Kisan Credit Card (KCC) Scheme. The KCC scheme was introduced in 1998. The model of the scheme is prepared by the National Bank of Agriculture and Rural Development (NABARD) on the recommendation of the R. V. Gupta committee to provide the means to agricultural needs.

Kisan Credit Card scheme is operated by commercial, cooperative and Regional rural banks. The scheme not only provides financial credit for agriculture purposes it

also supports allied activities such as fisheries and dairy farming. The study is mainly based on the awareness level of the Kisan credit card scheme among the farmers. Several factors to be considered for the study are awareness, Perspectives,

Access to credit, socio-economic factors and perceived benefits of KCC as main variables of the study.

SCOPE OF THE STUDY

Agriculture holds an important place in the development of the country. Hence the financial support for the field of agriculture plays a crucial role in helping farmers community for improved productivity. Hence the KCC scheme is chosen for the study as it's one of the schemes introduced for agricultural activities. To study about KCC scheme its primary thing to study the factors influencing farmers to adopt KCC to evaluate further thing. Hence by considering topic of the study we can evaluate the awareness level, perception of farmers and socio-economic factors influencing farmers.

OBJECTIVES OF THE STUDY

1. To study the details of Kisan Credit Card scheme

- To study the factors that influence farmers to utilize KCC scheme

RESEARCH METHODOLOGY

Data collection: The primary data is collected from systematically prepared questionnaires for the farmers. And the Secondary data is collected from the published research papers, websites of RBI and NABARD.

Sample size: The sample size used for the study includes the sample of 35 respondents from the Kalaburagi district itself.

Methodology: Once the data is collected the next step is to analyze the data, here the data is analyzed using SPSS 2.0 and the Cronbach's alpha method as its suitable for crosschecking the reliability of the considered variables and the inter dependency of them.

DATA ANALYSIS AND INTERPRETATION

The collected data is analyzed below into two parts whereas Part A includes demographic details of the respondents, and Part B includes the different variables considered to evaluate the factors influencing farmer's decision to adopt and utilize Kisan Credit Card Scheme benefits. Let us study the important factors considered under the study as follows:

Part-A

Demographic details of Respondents

Table 1: Gender of the respondents

Gender					
		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	Male	35	100.0	100.0	100.0

Table 2: Age of the respondents

Age (In years)					
		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	18-25	2	5.7	5.7	5.7
	26-35	14	40.0	40.0	45.7
	36-45	12	34.3	34.3	80.0
	46-55	5	14.3	14.3	94.3

Valid	Above 56	2	5.7	5.7	100.0
	Total	35	100.0	100.0	

Table 3: Educational qualifications of the respondents

Educational Qualification					
		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	Illiterate	5	14.3	14.3	14.3
	Primary	10	28.6	28.6	42.9
	Secondary	9	25.7	25.7	68.6
	Graduation	11	31.4	31.4	100.0
	Total	35	100.0	100.0	

Table 4: Land owned for agricultural purposes

Land owned for agricultural purpose					
		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	1-2 acres	9	25.7	25.7	25.7
	2-5 acres	14	40.0	40.0	65.7
	5-10 acres	10	28.6	28.6	94.3
	More than 10 acres	2	5.7	5.7	100.0
	Total	35	100.0	100.0	

Table 5: Duration of usage of Kisan Credit Card

How long have you been using the Kisan Credit Card?					
		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	Less than 1 year	1	2.9	2.9	2.9
	1-2 years	12	34.3	34.3	37.1
	2-5 years	18	51.4	51.4	88.6
	5.00	4	11.4	11.4	100.0

Table 6: Average amount sanctioned under KCC scheme

What is the average loan amount you usually avail through the Kisan Credit Card?					
		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	Less than 50,000	3	8.6	8.6	8.6
	50,000 - 1,00,000	11	31.4	31.4	40.0
	1,00,001 - 3,00,000	16	45.7	45.7	85.7
	3,00,001 - 5,00,000	4	11.4	11.4	97.1

Valid	Above 5,00,000	1	2.9	2.9	100.0
	Total	35	100.0	100.0	

Table 7: Frequency of Repayment

What is the average loan amount you usually avail through the Kisan Credit Card?					
		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	Less than 50,000	3	8.6	8.6	8.6
	50,000 - 1,00,000	11	31.4	31.4	40.0
	1,00,001 - 3,00,000	16	45.7	45.7	85.7
	3,00,001 - 5,00,000	4	11.4	11.4	97.1
	Above 5,00,000	1	2.9	2.9	100.0
	Total	35	100.0	100.0	

Table 8: Satisfaction about KCC scheme

		Freq- uency	Percent	Valid Percent	Cumu- lative Percent
Valid	Satisfied	18	51.4	51.4	51.4
	Neutral	10	28.6	28.6	80.0
	Dissati- sified	7	20.0	20.0	100.0
	Total	35	100.0	100.0	

PART-B

Factors influencing farmers to utilize KCC facilities

Table 9: Awareness of KCC

Reliability Statistics	
Cronbach's Alpha	N of Items
.903	5

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I am aware of the existence of the Kisan Credit Card (KCC) scheme.	14.0000	5.765	.713	.891
I have knowledge about the benefits offered by the KCC scheme.	14.3429	4.879	.781	.879
I understand the eligibility criteria required to apply for a KCC.	14.4286	5.252	.764	.880
I am familiar with the application process for obtaining a KCC.	14.1714	5.793	.732	.888
I know where to obtain information about KCC facilities.	14.4857	5.139	.822	.867

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
17.8571	8.185	2.8609	5

In the above table the reliability for awareness of KCC is calculated considering the variables are knowledge and understanding about application processes, eligibility criteria, interest rate and repayment terms of KCC. The

reliability is calculated with the help of Cronbach alpha method; the value of alpha is 0.903. which is highly reliable among the variables.

Table 10: Perspective Towards KCC

Reliability Statistics	
Cronbach's Alpha	N of Items
.855	5

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I believe that KCC facilities are beneficial for agricultural activities.	13.4000	5.424	.646	.832

I perceive KCC as a convenient source of credit for farming needs.	13.4571	4.667	.804	.787
I trust the reliability of KCC compared to other Credit options.	13.9429	7.055	.416	.879
I have a positive attitude towards adopting KCC facilities.	13.6286	5.064	.778	.795
I am willing to consider using KCC for my farming operations.	13.5714	5.487	.727	.811

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
17.0000	8.353	2.89015	5

Cronbach alpha method. The value of alpha is 0.855 which indicates higher reliability among the variables.

Table 11: Access to Credit

Reliability Statistics	
Cronbach's Alpha	N of Items
.818	4

In the above table the reliability of variables of perspective towards the KCC are considered. The factors include the benefits of KCC on agricultural activities and improved productivity. Hence the reliability of Perspective towards KCC is calculated with the help of

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I have easy access to credit facilities for agricultural purposes.	9.8571	2.714	.696	.749
I have sufficient collateral to obtain loans through KCC.	10.4000	3.541	.497	.834
I am confident in my ability to repay loans availed through KCC.	10.2286	3.476	.690	.761
I perceive KCC as a viable option to fulfil my credit needs.	10.1429	2.950	.722	.732

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
13.5429	5.314	2.30527	4

the loans. The result shows the value of alpha is .818 which is highly reliable among the variables considered.

Table 12: Perceived Benefits of KCC

Reliability Statistics	
Cronbach's Alpha	N of Items
.678	5

In the above table the reliability test is done from Cronbach alpha method to know the access to credit through KCC. The variables considered are having sufficient collateral to avail the loan and ability to repay

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I believe that KCC offers lower interest rates compared to other credit options	12.4286	3.370	.234	.696

I perceive KCC as providing timely and adequate credit support for farming.	12.0286	1.852	.526	.605
I consider KCC to be flexible in terms of loan repayment options.	12.3143	2.634	.504	.600
I believe that KCC helps in improving agricultural productivity and income.	12.4571	2.550	.431	.628
I see KCC as a means to access various financial services beyond credit	12.4857	2.669	.560	.585

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
15.4286	3.782	1.94461	5

From the above table it is tested to know the reliability of perceived benefits of KCC. The variables considered under this are flexibility in repayment, KCC as adequate credit facility and interest compared to other credit

options. It is found that the value of alpha is .678 which is just above .600 hence it is just acceptable among the variables.

Table 13: Socio-Economic Factors

Reliability Statistics	
Cronbach's Alpha	N of Items
.766	5

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
My level of education influences my decision to adopt KCC facilities.	11.5429	3.020	.368	.798
My income level affects my ability to utilize KCC for farming activities	11.3429	2.585	.748	.642
My landholding size is a factor in considering KCC adoption.	11.2571	3.020	.593	.706
My household size impacts my need for credit facilities like KCC.	11.4000	3.424	.419	.760
My location (rural/urban) influences my access to KCC and its utilization.	11.4857	2.963	.621	.696

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
14.2571	4.432	2.10522	5

The next variable of Socio-economic factor is taken to check the reliability of variables. The sub variables considered under this are level of income, landholding size, educational qualification and household size. The

Cronbach alpha method is used on mentioned variables and the value of alpha is .766 which is considered to be reliable among the variables.

Table 14: Peer Influence and Social Networks

Reliability Statistics	
Cronbach's Alpha	N of Items
.363	5

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
I am influenced by the experiences of other farmers who have adopted KCC	12.3714	1.534	.095	.393
Recommendations from friends or family members influence my decision to use KCC.	12.5714	1.723	.065	.395
Participation in farmer groups or cooperatives encourages me to adopt KCC.	12.5143	1.434	.152	.342
I receive information about KCC through informal networks in my community	12.7429	1.373	.392	.149
Peer pressure plays a role in my decision to adopt KCC facilities.	13.0000	1.529	.252	.262

Scale Statistics			
Mean	Variance	Std. Deviation	N of Items
15.8000	2.047	1.43075	5

In the above table the reliability test is done for the variable peer influenced and social network. The variables considered under this are beneficiaries influenced by family, friends, and other farmers. The result for this is the value of alpha is .363 which is unacceptable; hence the necessary changes to be made among the considered variables or it can be eliminated.

CONCLUSION

A study on the factors influencing farmers decisions to adopt and utilize Kisan Credit Card scheme Facilities- A case study of Kalaburagi district. In the study the main variables considered are awareness of KCC, perspective towards KCC, access to KCC, perceived benefits of KCC, socio-economic Factors, peer influence and social networks. The reliability of the variables is tested by using the Cronbach Alpha method. As a result, the first 5 variables are reliable and give positive response towards the study while the last variable is not reliable towards the variables considered. The study is done for

the Kalaburagi district, and the study gives a positive note among the variables considered.

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Audio Streaming using Li-Fi

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ABSTRACT

This paper focuses on Li-Fi, its applications, features and comparison with existing technologies like Wi-Fi etc. Wi-Fi is of major use for general wireless coverage within building, whereas Li-Fi is ideal for high density wireless data coverage in confined area and especially useful for applications in areas where radio interference issues are of concern, so the two technologies can be considered complimentary. Li-Fi provides better bandwidth, efficiency, connectivity and security than Wi-Fi and has already achieved high speeds larger than 1 Gbps under the laboratory conditions. By leveraging the low-cost nature of LEDs and lighting units, there are lots of opportunities to exploit this medium. Li-Fi is the transfer of data through light by taking fibre out of fibre optics and sending data through LED light bulb.

KEYWORDS : *LI-FI, LASER, Audio transmission, Solar panel, VLC.*

INTRODUCTION

In the era of overcrowded (data communication) world, Li-Fi is a new way of wireless communication that uses LED lights to transmit data wirelessly. Transmission of data is one of the most important day to day activities in the fast growing world. The current wireless networks that connect us to the Internet are very slow when multiple devices are connected. Also with the increase in the number of devices which access the Internet, the availability of fixed bandwidth makes it much more difficult to enjoy high data transfer rates and to connect a secure network. Radio waves are just a small part of the electromagnetic spectrum available for data transfer. Li-Fi has got a much broader spectrum for transmission compared to conventional methods of wireless communications that rely on radio waves. The basic ideology behind this technology is that the data can be transferred through LED light by varying light intensities faster than the human eyes can perceive. This technology uses a part of the electromagnetic spectrum that is still not greatly utilized- The Visible Spectrum, instead of Gigahertz radio waves for data transfer.

By Communication through visible light, Li-Fi technology has the possibility to change how we access the Internet, stream videos, receive emails and much more. Security would not be an issue as data can't be accessed in the absence of light. As a result, it can be used in high security military areas where RF communication is prone to eavesdropping.

OBJECTIVE

The objective of the project is to achieve audio and video streaming using Li-Fi technology that is using visible light spectrum as the medium of transmission. Digitalizing the Analog input and giving it to the LED lamp through the lamp driver circuit and reproducing it back at the receiver by using a photo diode sensor is the process implemented for it. The main purpose of Li-Fi technology is to overcome the defects of Wi-Fi communication and to avoid the hazardous effects caused by the other spectrums if implemented. Implementation of Li-Fi results in achieving high speed data transfer at very low cost along with an assurance of safety to the environment. indoor communication where it augments

Wi-Fi and cellular wireless communications which follow the smart city concept,

- communication wireless links for the internet of things (IOT),
- communication systems as part of intelligent transport systems (ITS),
- wireless communication systems in hospitals,
- toys and theme park entertainment, and
- provision of dynamic advertising in formation through a smartphone camera.

LITERATURE REVIEW

System Architecture: Li-Fi audio systems typically use a high- brightness LED for transmitting audio data, which is captured by a silicon photodiode (or solar panel) and then amplified for playback.

Audio Quality & Performance: Studies have demonstrated successful, real-time, high-fidelity stereo audio transmission using intensity modulation of visible light.

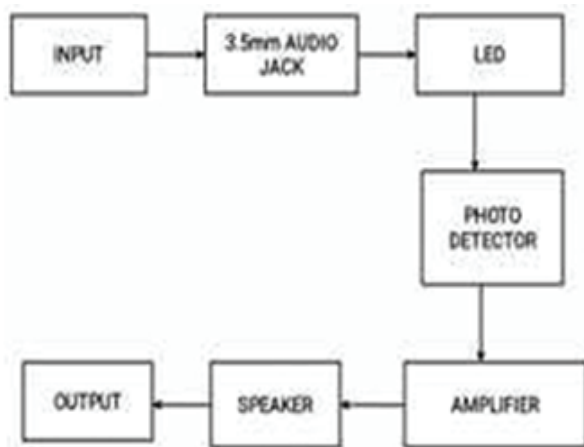
Advantages over Traditional Methods:

Security: Light does not penetrate walls, ensuring data confinement and high security.

Efficiency: Uses existing lighting infrastructure, making it a cost- effective and energy-efficient solution

Immunity to Interference: Free from electromagnetic interference, making it suitable for hospitals and aircraft.

Working



Basic Concept

Light Fidelity (Li-Fi) technology is a wireless communication system based on the use of visible light between the violet (800 THz) and red (400 THz). Unlike Wi-Fi which uses the radio part of the electromagnetic spectrum, Li-Fi uses the optical spectrum i.e. Visible light part of the electromagnetic spectrum. The principle of Li-Fi is based on sending data by amplitude modulation of the light source in a well-defined and standardized way. LEDs can be switched on and off faster than the human eyes can detect since the operating speed of LEDs is less than 1 microsecond. This invisible on-off activity enables data transmission using binary codes. If the LED is on, a digital '1' is transmitted and if the LED is off, a digital '0' is transmitted. Also these LEDs can be switched on and off very quickly which gives us a very nice opportunity for transmitting data through LED lights, because there are no interfering light frequencies like that of the radio frequencies in Wi-Fi. Li-Fi is thought to be 80% more efficient, which means it can reach speeds of up to 1Gbps and even beyond. Li-Fi differs from fibre optic because the Li-Fi protocol layers are suitable for wireless communication over short distances (up to 10 meters).

How it Works

The working of Li-Fi is very simple. There is a light emitter on one end i.e. an LED transmitter, and a photo detector (light sensor) on the other. The data input to the LED transmitter is encoded in to the light (technically referred to as Visible Light Communication) by varying the flickering rate at which the LEDs flicker 'on' and 'off' to generate different strings of 1s and 0s. The onoff activity of the LED transmitter which seems to be invisible (The LED intensity is modulated so rapidly that human eye cannot notice, so the light of the LED appears constant to humans), enables data transmission in light form in accordance with the incoming binary codes: switching ON a LED is a logical '1', switching it OFF is a logical '0'. By varying the rate at which the LEDs flicker on and off, information can be encoded in the light to different combinations of 1s and 0s.

RESULTS

The hardware transmitter circuit is connected and Pcb layout is done.

The LED transmitter circuit is connected and Pcb Layout is done.

The Photo Diode receiver circuit is connected and Pcb Layout is done.

The output of the transmitter and the glowing of the LEDs according to the given input is done and observed.

The output of the receiver and the audio input given is transmitted through the LED and played in the speaker without any noise.

The following are the pictures of the results of the transmitter and receiver blocks observed during the testing of the outputs.



FEATURES

On the transmitter side, when we connect 3.5mm jack to audio source LED will glow but there is no fluctuation in the intensity of light when the audio source is OFF. As soon as you play the audio, you will see that there is a frequent change in the intensity of light. When you increase the volume, LED's intensity is changing faster than the human eye can follow. A solar panel is so sensitive that it can catch small intensity change and correspondingly there is a change in the voltages at the output of the solar panel. So, when the light of LED falls on the panel, voltages will vary according to the intensity of light. Then voltages of solar panels are fed into an amplifier (Speaker) which amplifies the signal and giving the audio output through the speaker connected to the amplifier. The output will come as long as the solar panel is in contact with LEDs. You can put the LEDs at max. 15- 20cm distance from the solar panel to get clear audio output. You can further increase the range by increasing the area of solar panel and higher wattage Power LED.

CONCLUSION

Although there's still a long way to go to make this technology a commercial success, it promises a great potential in the field of wireless internet. A significant number of researchers 15 and companies are currently working on this concept, which promises to solve the problem of lack of radio spectrum, space and low internet connection speed. By deployment of this technology, we can migrate to greener, cleaner, safer communication networks. The very concept of Li-Fi promises to solve issues such as, shortage of radio-frequency bandwidth and eliminates the disadvantages of Radio communication technologies. Li-Fi is the upcoming and growing technology acting as catalyst for various other developing and new inventions/technologies. Therefore, there is certainty of development of future applications of the Li-Fi which can be extended to different platforms and various walks of human life.

FUTURE SCOPE

As light is everywhere and free to use, there is a great scope for the use and evolution of LiFi technology. If this technology becomes mature, each Li-Fi bulb can be used to transmit wireless data. As the Li-Fi technology becomes popular, it will lead to a cleaner, greener, safer communications and have a bright future and environment. The concept of Li-Fi is deriving many people as it is free (require no license) and faster means of data transfer. If it evolves faster, people will use this technology more and more.

Currently, LBS (location Based Service) or Broadcast solution are commercially available. The next step could be a Li-Fi WLAN for B2B market with high added value on specific business cases and could grow towards mass market. In the long term, the Li-Fi could become an alternative solution to radio for wireless high data rate room connectivity and new adapted service, such as augmented or virtual reality.

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Design of Residential Building Using AutoCAD

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ABSTRACT

This paper presents the architectural planning and design of residential and commercial spaces using the YQARCH methodology integrating modern design philosophies with environmental and cultural sensitivity. Unlike traditional CAD-based workflows, YQARCH emphasizes a holistic approach to design by incorporating advanced tools such as AutoCAD, Revit, and Building Information Modelling (BIM) to ensure both functional efficiency and aesthetic quality. The paper includes detailed plans for a residential house, sectional drawings, and furniture detailing. Through this approach, the paper will give detail on the practical application of professional architectural standards, highlighting the synergy between technology and design creativity. The result is a comprehensive and efficient design process that meets contemporary architectural requirements while promoting eco-friendly and contextually responsive solutions.

KEYWORDS : AutoCAD, YQARCH, Design, Drawing.

INTRODUCTION

Auto Cad is a computer aided design (CAD) software developed by Autodesk that is widely used in architectures engineering and construction (AEC) industries. It allows users to create precise 2D and 3D drawings, technical plans and digital models for various application.

Since, it released in 1982, Auto CAD has revolutionised traditional manual drafting, making the design process faster, more accurate and highly efficient. The software is used in fields such as architecture, mechanical design, electrical layout planning, urban development, and interior design.

Importance of AUTOCAD in design and engineering AUTO CAD is a powerfull tool that provide

- High precisions- Ensure accurate dimension and Scaling
- Efficiency – saves time by automatic repetitive task.

- Visualization 3D modeling helps in understanding real world application -3D
- Modification flexibility- edits and modification can be made easily.
- Industry Standards Compliance – Supports various international drafting standards.
- Engineers and architects rely on AutoCAD for blueprint creation, product design, urban planning, and structural analysis.

Key features of Auto CAD

Auto CAD offers a wide range of features including 2D Drafting and Annotation

- Creation of floor plan elevations and sectional views.
- Precise dimensioning and annotation tools.
- Layer management for organizing drawings
- 3D Modelling & Visualization.

- Solid, surface, and mesh modelling for realistic 3D objects

Automation and Customization

- Auto LISP and VBA scripting for automatic tasks.
- Parametric constraints for intelligent design changes.
- Dynamic blocks for reusable design elements.
- File Compatibility & Cloud Integration Supports multiple file formats: DWG, DXF, PDF, and STL
- Integration with cloud storage and mobile apps for remote access. Collaboration tools for team projects.

Application of Auto CAD

Auto CAD is used across various industries such as

- Architecture & Civil Engineering Designing residential and commercial buildings.
- Planning Road networks and infrastructure.
- Landscaping and urban development.

YQARCH is a professional architecture and design firm known for its innovative and sustainable architectural solutions. The firm focuses on blending modern design principles with cultural and environmental sensitivity. YQARCH offers a range of services including architectural design, interior design, urban planning, and project management.

The firm emphasizes the use of advanced tools and software, such as AutoCAD, Revit, and BIM, to ensure precision and efficiency in design and execution. YQARCH has gained recognition for its commitment to design excellence, client satisfaction, and environmentally conscious practices. Their portfolio spans residential, commercial, institutional, and public projects, showcasing versatility and creativity.

YQARCH aims to create spaces that are not only functional but also aesthetically pleasing and sustainable, pushing the boundaries of modern architecture while respecting local contexts and cultures.

LITERATURE REVIEW

- Akinlabi, E.T. (2013) emphasized AutoCAD's crucial role in mechanical design. His work

demonstrated how the software aids in visualizing and simulating real-world mechanical systems, enhancing precision and reducing development time, especially in stress analysis and component fit testing.

- Wang, H. (2015) discussed AutoCAD's applicability in civil engineering. He highlighted how engineers use it to draft, analyze, and quickly modify infrastructure layouts such as bridges and road networks, improving project turnaround and accuracy in structural calculations.
- Zhu, J. (2011) showcased AutoCAD's impact on architectural design by improving drafting precision and enhancing 3D visualization. His work underscored the software's ability to produce accurate blueprints and presentation-ready models.
- Patil, S.R. & Kulkarni, G.M. (2016) conducted a comparative study revealing that AutoCAD-based drafting significantly reduces time consumption (up to 40%) over traditional manual methods, enhancing both speed and consistency in output. Study demonstrated that combining both tools improves spatial data representation in urban planning, aiding city development strategies.
- Ahmed, M.M. (2012) explored the integration of AutoCAD with Geographic Information Systems (GIS). His study demonstrated that combining both tools improves spatial data representation in urban planning, aiding city development strategies.
- Chung, W. (2010) focused on the educational aspect, analyzing AutoCAD's learning curve among engineering students. Although challenging initially, students benefited long-term through enhanced design capabilities and technical competence.
- Singh, D. & Verma, A. (2018) utilized AutoCAD to model residential structures in 3D. Their research concluded that AutoCAD not only facilitated better visualization for clients but also optimized material estimation and structural detailing.
- Olapiriyakul K. & Adhikari, A. (2014) investigated the software's application in green building simulations. They successfully used AutoCAD

for thermal and energy performance analysis, promoting sustainable architectural practices.

- Srinivasan, D. (2017) highlighted the automation features of AutoCAD, such as macros and scripts. He argued these capabilities drastically reduced redundant tasks and improved project efficiency in design iterations.
- Ali, H. & Abbas, M. (2019) evaluated AutoCAD’s role in the prototyping phase of mechanical components. They emphasized its seamless integration with CNC machining and 3D printing tools, promoting design validation before mass production.

OBJECTIVES

1. To Develop 2D Architectural Drawings.
2. To Optimize Space Planning Through Drafting Tools.
3. To Generate Working Drawings for Construction.
4. To Present a Complete CAD Portfolio of the Project.

METHODOLOGY

The design work was carried out using AutoCAD software integrated with the YQARCH plugin for enhanced architectural drafting efficiency.

- Project requirements were identified, and a conceptual layout was developed based on spatial needs and design standards.
- The YQARCH tools were utilized to accurately draw walls, insert doors/windows, and define room layouts within the 2D floor plan.
- Elevations and sectional views were prepared to represent vertical detailing and architectural aesthetics.
- Column positioning and foundation layouts were marked as per structural planning and design alignment.
- Shuttering and structural detailing were added using standard YQARCH components to ensure clarity and precision.
- All drawings were properly annotated and

dimensioned, following industry standards for readability and accuracy

- Layer management was implemented to organize architectural, structural, and interior components systematically.

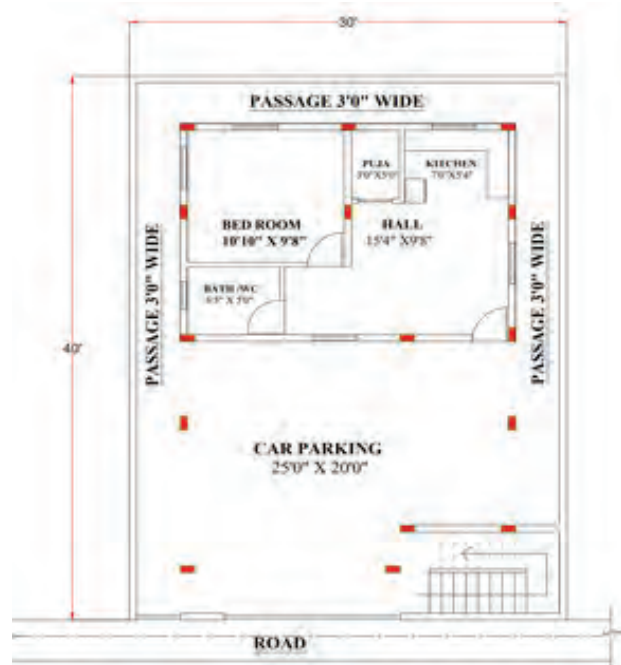


Fig. 1. Ground Floor Plan

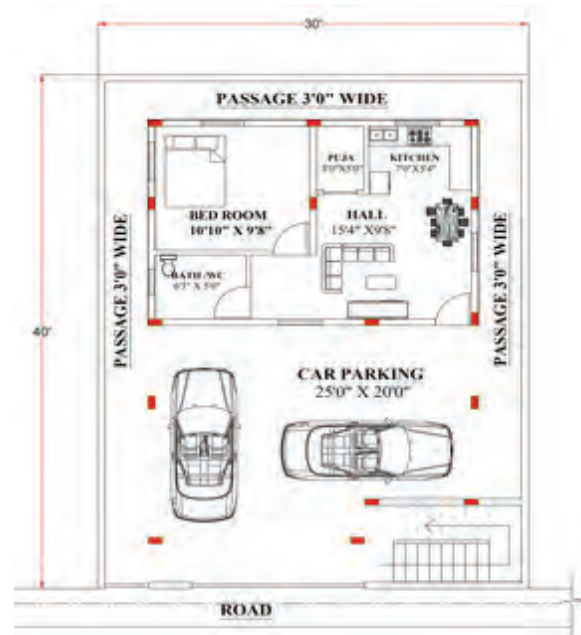


Fig. 2. Interior Floor Plan

RESULT

- AutoCAD can be used for 2D,3D drafting but YQArch can be used for enhancing for architectural task.
- AutoCAD consist of standard Cad Tools, layers, objects etc. in the same way YQArch consist of architectural specific tool, block management.
- Auto CAD is a versatile and can be used for a wide range of industries, but YQArch is primarily focuses on architectural design.
- Auto CAD provides the foundation for creating drawings, while YQArch is a tool that adds specific functions like Foundation etc.

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