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4D PRINTING: A REVIEW ON ADVANCES AND CHALLENGES

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Abstract
Three-dimensional printing has become one of the most popular and useful manufacturing technology in recent times. Three-dimensional printing is an automated process of making the three dimensional objects from computer aided design (CAD). During earlier stage of developments, 3D printing was considered as the technology of making prototypes only. But with the improvements in the accuracy, surface finish and reproducibility, it becomes popular among various manufacturing sectors. In recent times researchers have added one more dimensions in conventional 3D printing to change the 3D static construct into dynamic structure. The fourth dimension is time and this technology is famous with name of 4D printing. 4D printed objects have the extra feature of changing their shape and properties with time when subjected to external stimuli. This research article will be discussing of principles of 4D printing technology with recent advancements, challenges and possible future directions. Last section is dedicated to 5D and 6D printing technology and their application in food sector.

Keywords
4D printing, Three-Dimensional Printing, Smart Materials

1. Introduction

4D printing is the advanced version of 3D printing technology. 3D printing is modern manufacturing technology of producing three dimensional solid objects from 3D CAD (computer aided design) model. Complete computer aided design model is first converted into several layers. With the help of machine these layers added one over the other to make the complete three dimensional object. 3D printing also called by some other names such as AM (additive manufacturing), RM (rapid manufacturing), RP (rapid prototyping) and DDM (direct digital manufacturing). 3D printing technology enjoys various advantages over traditional subtractive manufacturing such as complexity of object, product customization, ellimination of tooling cost, no need of casting prototype, fast speed for low to medium size products and more design freedom. During early phase of develooements 3D printing technology was considered as the technique for making prototypes only. But with the improvement in speed, accuracy, reproducibility and cost, 3D printing gain popularity in various manufacturing sectors. Conventional 3D printing used for making static structures (using single object)

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which can not fulfill requirements for dynamic functions for applications like adaptive blades of wind turbine and automatic packaging (self folding). For meeting demands of dynamic functions, fourth dimension in the form of time added to existing 3D printing technology and this technology is called as 4D printing [1]. 4D printing provides designers opportunities for multilateral designing and extra programmed functionality with reduced production time [2]. Due to better utilization, material efficiency improves in 4D printing process. This paper discuss various aspects of 4D printing technology.

2. Principles of 4D printing technology

4D printing may defined as "a process of adding dynamic feature in the conventional 3D printing technology using smart materials with well programmed design". 4D printing technology was first explained during a conference in 2012 at massachusetts institute of technology (MIT). Since than 4D printing become one of most popular research domain for researchers of various deciplines. 4D printed construct are dynamic in nature i.e ability of changing shape and property with time. Mostly 4D printing process is done with multimaterial printing where one or more material in a smart material [3]. Most important elements associated in 4D printing, includes printing methods, the materials, the external excitation, and the programming [4]. An air circulation system may be integrated with conventional fused deposition modeling printing technology to obtained the required dynamic results [5].

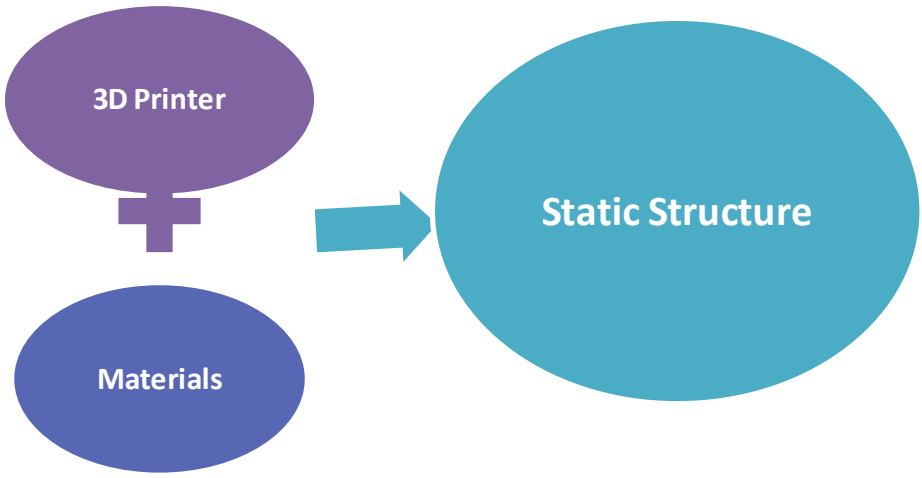


Fig. 1. Three-Dimensional Printing

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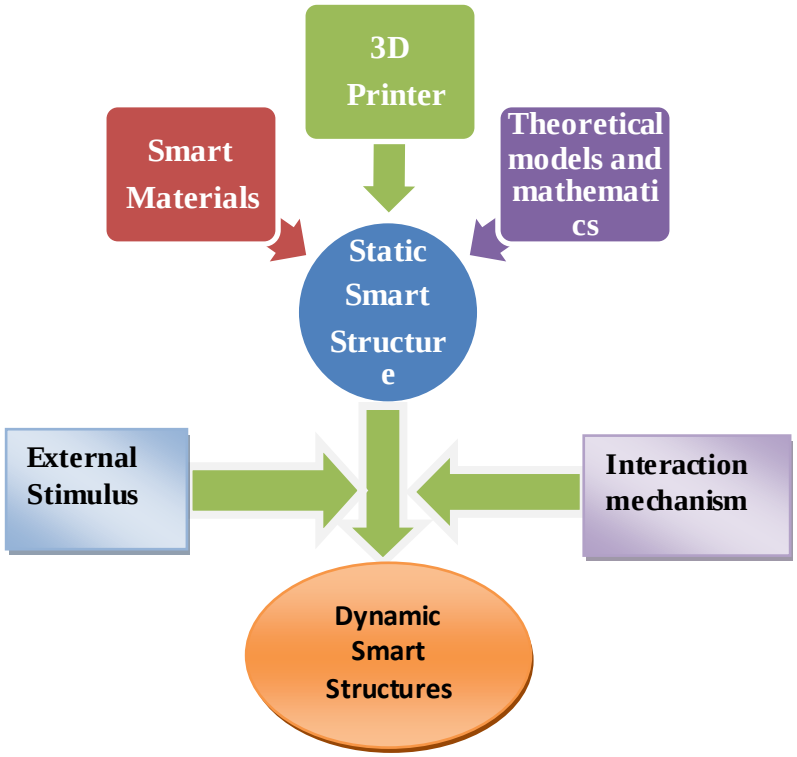


Fig. 2. Four-Dimensional Printing [6]

As shown in fig 2. 4D printing process starts with the 3D printing of smart materials with the help of mathematical modeling to make a static smart structure. This static smart structure is convert into dynamic smart structure when exposed to external stimulus with proper interaction mechanism. Smart materials are those materials which respond (i.e changes their shape and properties) to external stimuli. External stimuli may be heat or temperature, light, moisture or water, current, ph and magnetic field. Smart materials also famous with other terms namely intelligent materials, responsive materials and programmed materials. 4D printing may also defines as a process in which 3D printed objects are programmed to independently transform over time in response to external stimuli (such as heat, Moisture, light, wind and electricity). 4D printed objects self assebled (due to chemical reaction) under external stimuli of moisture, heat and air. Most of the recent research in 4D printing is focusses on the shape changing ability of the material [7]. With these shape changing ability 4D printed objects becomes suitable for various applications such as lockers, toys and lifters. Objects created by 4D printing technology offers better

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performance and quality as compare to conventional techniques. Biodegradability, low carbon and low mass are the eco friendly features of 4D products [8]. Due to self assembly of the material the total number of parts in the product gets reduced [9].

2.1 Critical elements in 4D printing process

Various elements are crucial in 4D printing process like selection of suitable material, external stimulus, printing technique, mechanism of interaction and modeling.

2.1.1 Material selection in 4D printing

Material selection in 4D printing are based on the two aspects i.e printability and ability of material to respond to external environmental stimuli [10]. Printability mainly depends on the viscosity of the material. Viscosity (or rheology) can be improved by various additives called as rheology modifiers. Materials which changes their shape and properties when subjected to external stimuli are known as smart materials or metamaterials or programmable materials [11]. Limited materials are available for 4D printing but researchers are working to develope new materials for 4D printing process. Table 1 listed the various types of smart materials with their properties and applications.

Table 1- Smart Materials in 4D printing

Smart materials for 4D printing	Properties	Applications
SMAs (shape memory alloys)	• Regain original shape when heated above their transformation temperature • Examples are nickel- titanium based SMAs	• Mechanical, • Eletrical, • Aerospace, • Implants, • Robotics
SMPs (shape memory polymers)	• Can programmed to remember a defined shape[6] • Return to programmed shape when exposed to certain stimuli • Possess dual-shape properties during conversion from temporary to permanent structure • Examples are poly-lactic acid, Polytetrafluoroethylene, and ethylene-vinyl acetate	• Smart medical implants • Tissue scaffolds • Medical devices
LCEs (liquid crystal elastomers)	• Formed by blending of single smart materials with a polymer	• Actuators, • Soft robots

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	network i.e combining properties of both elastomers and liquid crystals [6] • Show a various dynamic responses to heat and light (external stumuli) • Direction of deformation can be controlled • Anisotropic behaviour used to creat complex shape changes like bending and twisting	• Sensors
SMHs (shape memory hydrogels)	• 4D bio-constructs having ability to self fold or unfold in external stumuli [12] • Capable of responding to moisture or water, pressure, electric field, magnetic field and heat. During contact with moisture, hydrogels can experience a volumetric strain upto 200 percent	• Application Area incluides • Bio printing of tissues, • Micro-robot(for targeted drug delivery) for treating tumors (cancerous)

In recent times researchers in the field of material science are looking to develope materials which can mimic nature [13]. Nature teach us principle of adaptation, transformation, self-organization, and self-healing. Researchers are working towards incorporating these properties in the material as much as possible.

2.1.2 External Stimulus

External stimulus is required to apply for initiating the changes in shape and properties of 4D printed object. Researcher have applied a variety of stimuli namely heat, moisture, current, electric field, magnetic field, pH etc. Selection of stimulus depends on the application and desired output from 4D printed construct. Smart materials which is controlled by magnetic field generally shows large deformation rate with easy contol [10].

2.1.3 Printing Techniques

Various additive manufacturing or 3D printing processes can be used to print 4D objects as shown in fig.3. Additive manufacturing process in 4D must be able to print multimaterials [8]. Basic principle of all AM processes are same (adding materials in the form of layers)

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difference is mainly in the method of layer formation and raw material handling. Materials must be compectible with additive manufacturing process. Every printing process have advantages and disadvantages (like surface finish, accuracy, ease of material handling, speed etc). Selection of printing technology depends upon the requirements of products like speed, accuracy and surface finish.

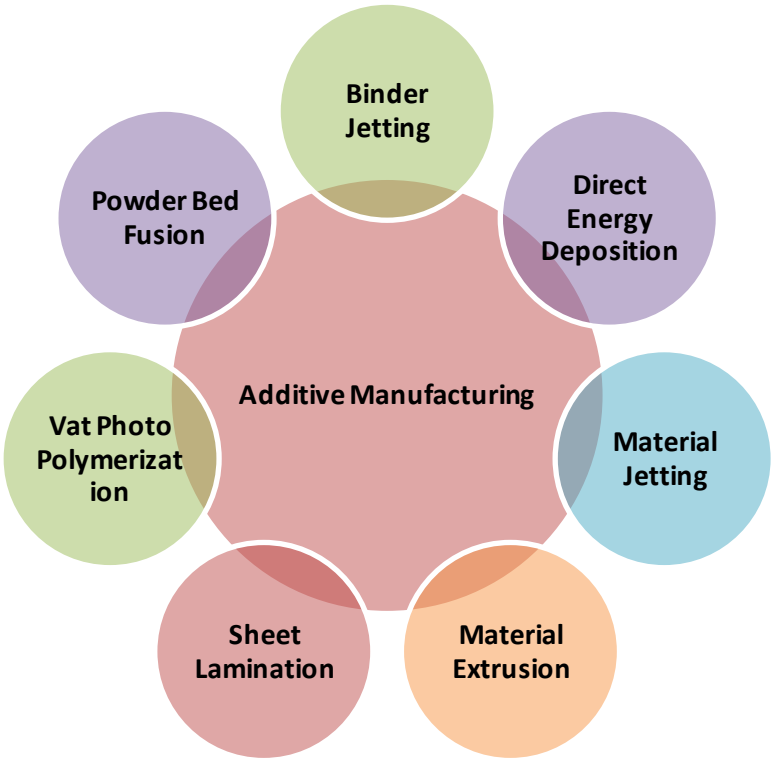


Fig.3. Classification of AM processes [13]

2.1.4 Mechanism of Interaction

The desirable shape of a printed object can not be obtained only by exposing the smart material in external stimulus but a suitable interaction mechanism is also required. For example thermo-mechanism, electro mechanism
Steps of thermo-mechanism-
Step 1- Deformation of printed object at high temerature with application of external load
Step 2- Deformation at low temperature while maintaining external load
Step 3- Unloading of printed object at lower temperature and obtained desired shape
Step 4- Original (or primary) shape is regained by heating the printed object
In electro-mechanism electric field acts as indirect stimulus which increase the operating

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temperature above the transformation temperature i.e temperature required for transformation by using resistance heating effect [11].

2.1.5 Laws of 4D Printing

Farhang momeny et al. define 4D printing using three different laws-
According to first laws- shape morphing behaviour of multimaterials is due to comparative expansion between active and passive elements. According to second law- four physics involve in shape morphing behaviour of the multimaterials i.e diffusion of mass, expansion due to thermal effect, molecular transformation and organic growth. Third law tells about time dependency of shape morphing behaviour of matimaterials [14].

3. Recent Advances in 4D Printing

Ability of 4D printed objects to self-assemble, adaptation of environmental changes and programmability (which can design to respond to specific stimuli) are the main advancements in 4D printing technology in recent times. Transformation functions in 4D printed objects are bending, angular deformation, folding, change in size (expansion and contraction), and changes in property. Many researchers have explored the area of 4D printing in their research. Moslem Mohammadi et al. developed a sustainable robotic Joints [15] by 4D Printing with Variable Stiffness. DRL (Deep Reinforcement Learning) controller were used to control the soft link and joint mechanism. They added Carbon fibre string in a S-spring shape poly lactic acid (PLA) filament. S-spring shape structure with carbon fiber string were placed on the joints of human limbs and performance were observed. Farhang Momeni et al. fabricated an actual plant leaf-mimetic wind blade by 4D printing [8]. Paunovic et al. explored the 4D printing for biodegradable elastomers with tailorable thermal response at physiological temperature [16]. Zixuan Kang et al. developed a sweet potato by 4D printing enriched with cricket powder and explored its colour changing ability in different values of pH [17]. Guiwei Li et al. fabricated biomimetric dome structure array by 4D printing and explored its dynamic nature [18]. Duigou et al. explored 4D printing of continuous flax-fibre based shape-changing hygromorph biocomposites [19].

4. Applications of 4D printing technology

4D printing is in developing stage still have various application areas including medical field, soft robotics, consumer goods, self evolving structures & piping system and aerospace industry.

4.1 Medical Applications

3D printing of biocompactible materials (that evolve with time) are refered to 4D bioprinting. 4D bioprinting possess several advantages over conventional tissue

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engineering such as cell positioning accuracy, high density tissue fabrication and fabrication of large engineering tissue. Kang et al. have shown various 4D printed biomaterials like self folding cell origami. Major applications of 4D bio-printing are drug delivery, orthopedics, medical devices, tissue engineering and dentistry [20]. Atchara chinnakorn et al. discussed about mechanism of approach in 4D printing technology for the cancer therapeutics [21] .

4.2 Soft Robotics

Conventional robotics used hard materials i.e metals, hard plastics, and ceramics for making robots. Such robots are designed for specific applications and specific environment [7]. If there is any changes occurs in environment, they can not adjust. Large deformations and flexibility is intolerable for these robots. To deal with such limitations Soft robots are developed using soft materials like EAPs(electroactive polymers) which are flexible like humans. Soft robots can adapt to the environmental condition and having ability to vary their stiffness. 4D printing are best suitable for the developement of soft robotic. Controlling and durability are the main challenges in soft robotic. Researchers are working towards developements of more materials for better actuation and control in soft robots.

4.3 Self Evolving Structure & Piping System

Moisture sensitive structures can be make using 4D printing which regain their original shape when comes in contact with moisture or water. Earlier mechanical degradation occurs in structure due to continuous wetting and drying but new multimaterials elliminate such problems. 4D printing have shown potential application in producing self repairing piping system which can change diameter as per the prevailing conditions (flow rate). 4D printing technology developes adaptive and responsive infrastructure like a printed bridge which can redistribute load quickly during adverse conditions [22].

4.4 Consumer Goods

3D printing provides cutomization of products for customers and 4D printing add the features of dynamic design by which product can adjust itself in environment changes and provides better performance to customer. 4D printing materials can print adjustable shoes for different conditions like rain, grass or hard surface.

4.5 Aerospace industry

Presence of smart materials along with other materials greatly inhence the performance of aerocraft (mainly by shrinking application). Automated controlled 4D printed air inlet parts was developed collectively by skylart tibbits and airbus [23]. Many recent advancements in 4D printing area for propulsion elements have shown great results and provide future direction of improvements in aerocraft industry.

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5. Challenges in 4D Printing technology

4D printing is a new technology which is in its initial phase of developement. There are lots of challenges which needs to be overcome to utilize the full potential of 4D printing. Challenges mainly related to design and scalability, related to avalability of suitable materials and challenges related to technology.

5.1 Challenges related to design and scalability

Smart materials are having ability to change their shape and properties in various environmental conditions [24]. Hence smart materials required special type of programming or designing to achieve the desired result. Very less research work observed towards the environmental impact of 4D printing process. Scalability is another challenging area for 4D printing as large scale applications are needed for worldwide acceptance of technology. Many researchers have explored the application of 4D printing application for making small objects like sensors, and actuators [9]. But very less researchers have explored the utilization of 4D printing for making large objects like buildings [22].

5.2 Challenges related to availability of suitable materials

There are challenges related to availability material and handling of materials during functionality in 4D printing process. Till now limited materials are available for 4D printing technology. Smart materials required additional care during printing process due to their high sensitivity. Few materials degrade in moisture environment (shape memory alloys) and few can degrade with repeated wetting and drying process (hydrogels). Some materials required additives for 4D printing processes for producing desired effects. Compactibility of smart materials with 3D printing technology leads to big challenge for researchers. More smart materials needs to be developed which can easily print and will not degrade their properties during their functionality.

5.3 Challenges related to technology

3D printers which can print smart materials are available in very limited numbers across the world. Polyjet 3D printing and selective laser melting are mainly used for making 4D structures. In case of polyjet printing technology materials must be in liquid state and responsive towards the ultraviolet (UV) rays. For SLM (selective laser melting) process material must be in powder form. Hence limited smart materials can be used in 4D technology. New technologies needs to be innovated for printing more smart materials. For the exploration of new technology by different researchers, resources in terms of 4D printers are required. 4D printing is a complex process as compare to 3D printing because of involvement of the smart materials. Developement of smart materials for specific application in 4D printing is a complicated procedure.

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6. Future direction

Exploration of full potential of 4D printing technology needs collaborative research in the field of material science, nanotechnology, biotechnology and engineering. In recent times researchers are mainly focus on shape changing ability of 4D printed structures but various other functionality areas needs to be studied. Multi-functional ability of 4D printed structures will definately brings revolution in manufacturing sector. Researchers should work towards the more controlling of stimulus response rate so that desired dynamic smart object can be make. Long term durability should be imparted into the smart 4D product [25].

6.1. 5D and 6D printing

4D printing technology provides dynamic structure but it required external stimulus for this dynamic structure. 5D and 6D printing can over come the limitatation of 4D printing. 5D is a combination of both additive and subtractive manufacturing. 6D printing used smart materials with 5D printing technology .5D and 6D printing finds application in food sector for making very complex shapes which are otherwise impossible to make with conventional methods. In case of 5D printing 5 axis (3 movements and 2 rotational) are used to make the complex shape object. Whereas 6D Printing process produced stronger food related products with higher responses to external envoronmental stimuli [26].

Table 2 – Description of Axis in 5D Printing

Axis of 5D Printing	
Axis 1	X
Axis 2	Y
Axis 3	Z
Axis 4	Movable Print Head
Axis 5	Movable Print Bed

7. Conclusion

In this research paper , principles of 4D printing technology, advances in 4D printing technology, applications of 4D printing technology, challenges in 4D Printing technology and future scope were reviewed. 3D printing of smart programmable materials are termed as 4D printing. Time is the fourth dimension in 4D Printing technology. 4D printed objects deforms with time when exposed to external stimuli. Type of deformation (like swelling,bending,folding) depends upon nature of external stimuli (heat,moisture,magnetic field,electric field). Application areas of 4D printing includes medical field, soft robotics, consumer goods, self evolving structures & piping system. Challenges in 4D printing

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technology mainly related to design and scalability, avalability of suitable materials and technology. With the collaborative researches in the field of material science, engineering, nanotechnlogy and biology the future of 4D printing technology seems to be very promising. Researchers are expecting to explore the full potential of 4D printing technology in near future and develop more multi-functional 4D products.

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ENHANCEMENT OF THERMO HYDRAULIC EFFICIENCY IN A CHANNEL FLOW USING DELTA TYPE WINGLET VORTEX GENERATOR

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Abstract

Thermo hydraulic efficiency of Heat Exchanger can be augmented by using Delta type winglet Vortex Generator. The comparison is also on the basis of the Heat Transfer factors; Colburn Factor, Friction Factor and Thermo hydraulic efficiency/ Performance Evaluation Criterion (PEC) have been drawn between without winglet and with winglet on a rectangular plate.The rectangular plate dimensions are considered 300mm*200mm*4mm, in which 12 Thermo couples are fitted for measuring the effect of temperature and pressure difference. The experimental procedure repeats two times, first without a winglet and the second time it is performed with a winglet. The comparison is to find out on the basis of Heat Transfer factors; Colburn Factor, Friction Factor and Performance Evaluation Criterion (PEC). Using Delta type Vortex Generator Thermo hydraulic efficiency of Heat Exchanger is enhanced up to more than 11%.

Keywords

Thermo hydraulic efficiency, Heat Exchanger, Delta type Vortex Generator, Winglet/ Vortex Generator.

1. INTRODUCTION

In heat exchanger thermal equipment, air act as a medium. Usually, phase-transform heat exchangers have a more significant heat transfer coefficient than air. Heat transfer augmentation apparatus or systems may help attain major cost-cut and energy in these types of applications where one fluid's thermal resistance proves supremacy. The progress of surfaces with high performance is an important and exciting area as the above-illustrated circumstances are usual and broadly accepted in industries for airside heat transfer augmentation(Hiravennavar, Tulapurkara, and Biswas 2007). The heat transfer coefficient may be enhanced by using extensive surfaces.

(Zhou and Ye 2012) showed the results that the CTWP had the best thermo-water powered execution in ultimately violent locale due to the smoothed-out design and

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subsequent low strain drop, demonstrating the benefits of including this type of vortex generators for heat move improvement and used dimensionless variables to compare and contrast conventional VGs with rectangular, trapezoidal, and delta winglets and tentatively investigated the representation of a few new vortex generators with curved trapezoidal winglets (CTW). (Esmaeilzadeh, Amanifard, and Deylami 2017) identified an anticipated state mathematical diversion used to examine the warm and liquid stream qualities of a terrible end layer for a level channel in an immaterial power exchanger. (Sarangi and Mishra 2017) studied the preservation conditions of mass, power, and energy, mathematically reviewed heat move improvement and strain loss of a balance and-chamber HE with rectangular winglet pairs. At various Reynolds numbers, it was agreed that the stream was laminar. (Wu et al. 2012) familiarized with two novel edge tube surfaces with two lines of chambers arranged in a staggered plan of varying widths to further foster the power move of the balance tube surface. (Modi, et al. 2020) examined the thermo-water-driven execution of FTHEs. They examined a variety of RWVGs with and without roundabout-poked holes (openings 1, 2, 4, and 6). The procedures of RWVGs are set up so that stream down (CFD) travels behind the circuitous chambers to increase the board's wakefulness. (Välikangas et al. 2018) focused on the effects of VGs. A coupled Open Foam open source solver was utilized to numerically settle the model in light of the fact that the coordinated grid gave both strong and fluid spaces. (Sinha et al. 2017) investigated as a plate-blade heat exchanger's mathematical upgrade by employing two lines of winglet. The findings indicate that the execution of the CFU design was the best among the various VG courses of action in terms of intensity shift and quality element. The new Reynolds number ranges from 250 to 1580.(Sadeghianjahromi et al. 2020) analyzed a number of novel improvements related to the airside execution of cylinder and wavy blade heat exchangers.

(Hou et al. 2020) performed erosion mix welding, divergent butt joining of 6061 aluminum and financially unadulterated copper with differing apparatus offset esteem, as was reviewed. (Jang, Hsu, and Leu 2013) represented that block-type VGs are used for tube heat exchangers and thermal-hydraulic characteristics are studied for 3-dimensional laminar in-lined. Also, a staggering plate fin tube is used for exchanging heat.(Ke et al. 2019) investigated the assault point of DWVGs in straight and wavy finned-tube heat exchangers using mathematical analysis.(J. Gong et al. 2013) utilized mathematical analysis to investigate the assault point of delta-winglet. Consequently, three-layered mathematical recreation data and artificial brain network-based multi-objective hereditary calculations were utilized. Varun Kumar et. al. research for the increase of the efficiency in their research.

2. EXPERIMENTATION

The instrument used for this research is named Wind Tunnel. The wind tunnel is generally used to measure air effects on any object. The shape of the winglet is approximately venturimeter type, as shown in figure 1.

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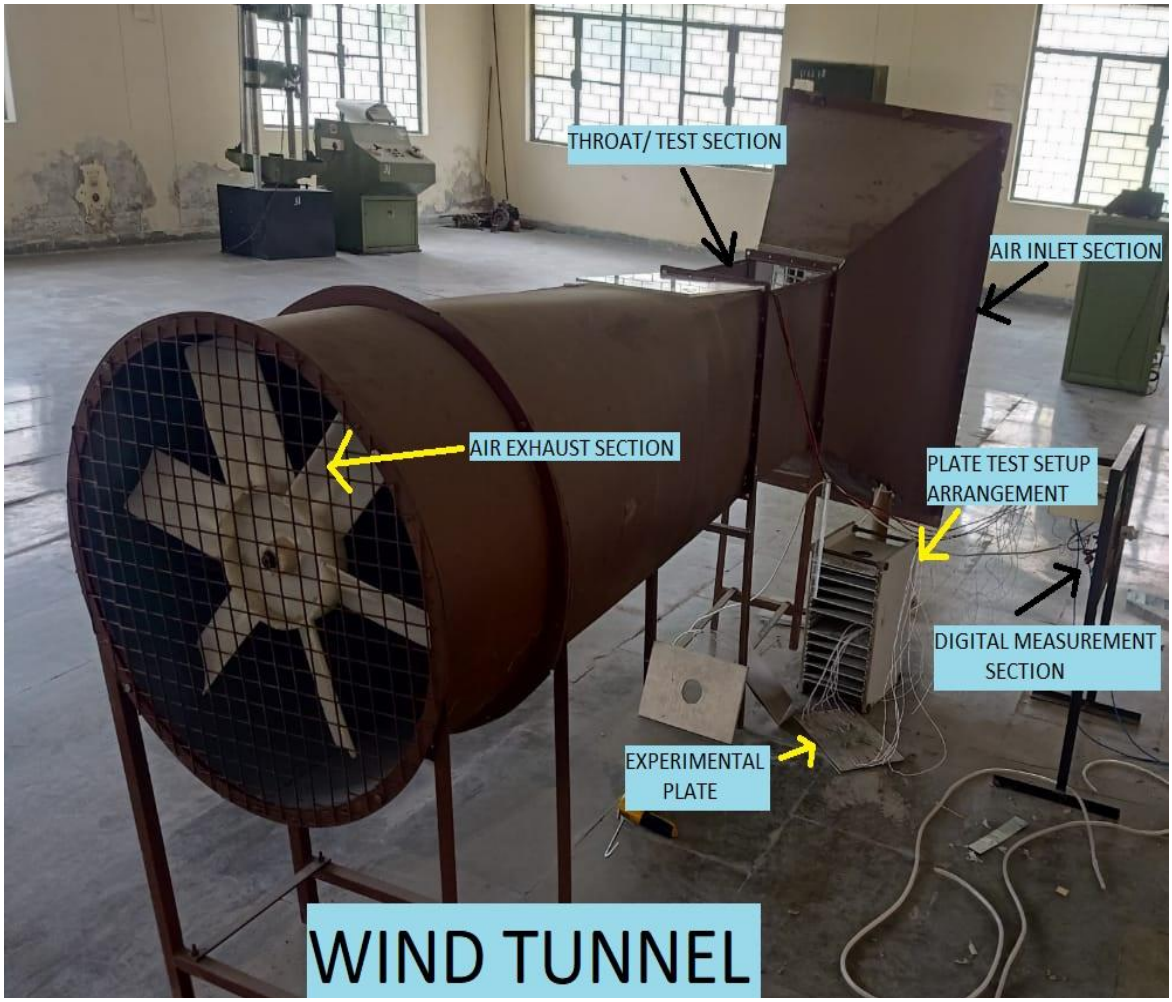


Figure 1: Wind Tunnel Experiment

2.1 RECTANGULAR FIN PLATE

The focal point of our experimental investigation is the rectangular fin plate. The experimental plate is used for each and every experiment. We are made up of experimental plates in the rectangle shape. The plate is 300 mm by 200 mm by 4 mm. We employed 13 rectangular fin plates for our investigation, but only one of the plates which is fitted in the middle of the other plate was taken into consideration for the final experiment. The laminar flow of air is converted by the remaining 12 plates. But even if the laminar flow is produced by the honeycomb, the experimental yields an accurate reading, therefore these 12 plates are also utilized to produce further laminar flow.In these studies, we make use of thirteen plates, with a 28 mm pitch between each plate.Figure 2 shows the rectangular fin plate which is used for performed the experiments.

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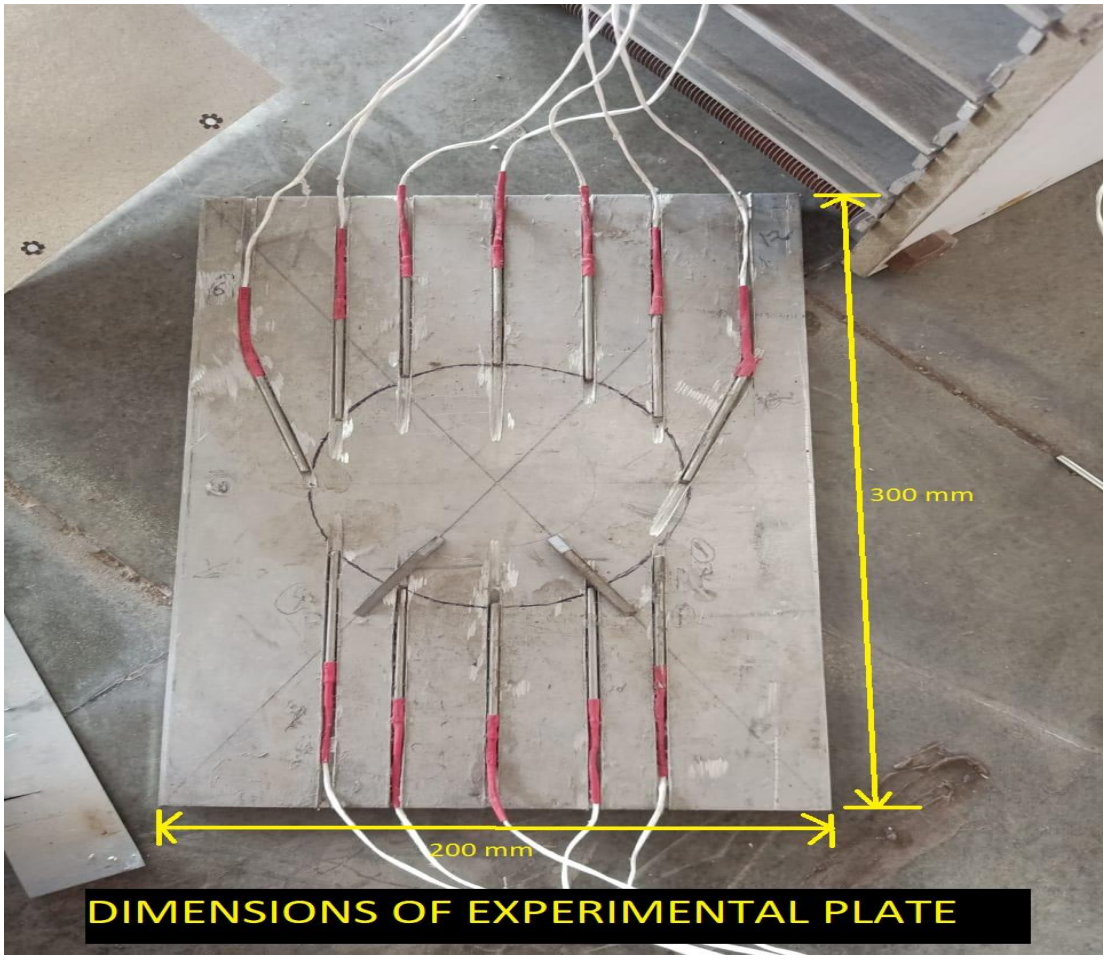


Figure 2: Experimental Rectangular fin plate

2.2 PLATE TEST SET UP

There are 13 fixed plates, whereas only one plate is considered for experiment work. The dimensions of this plate arrangement is 43 cm * 22.4 cm * 30.2 cm with all boundaries. Figure 3 shows the plate set up arrangement with experiment plate.

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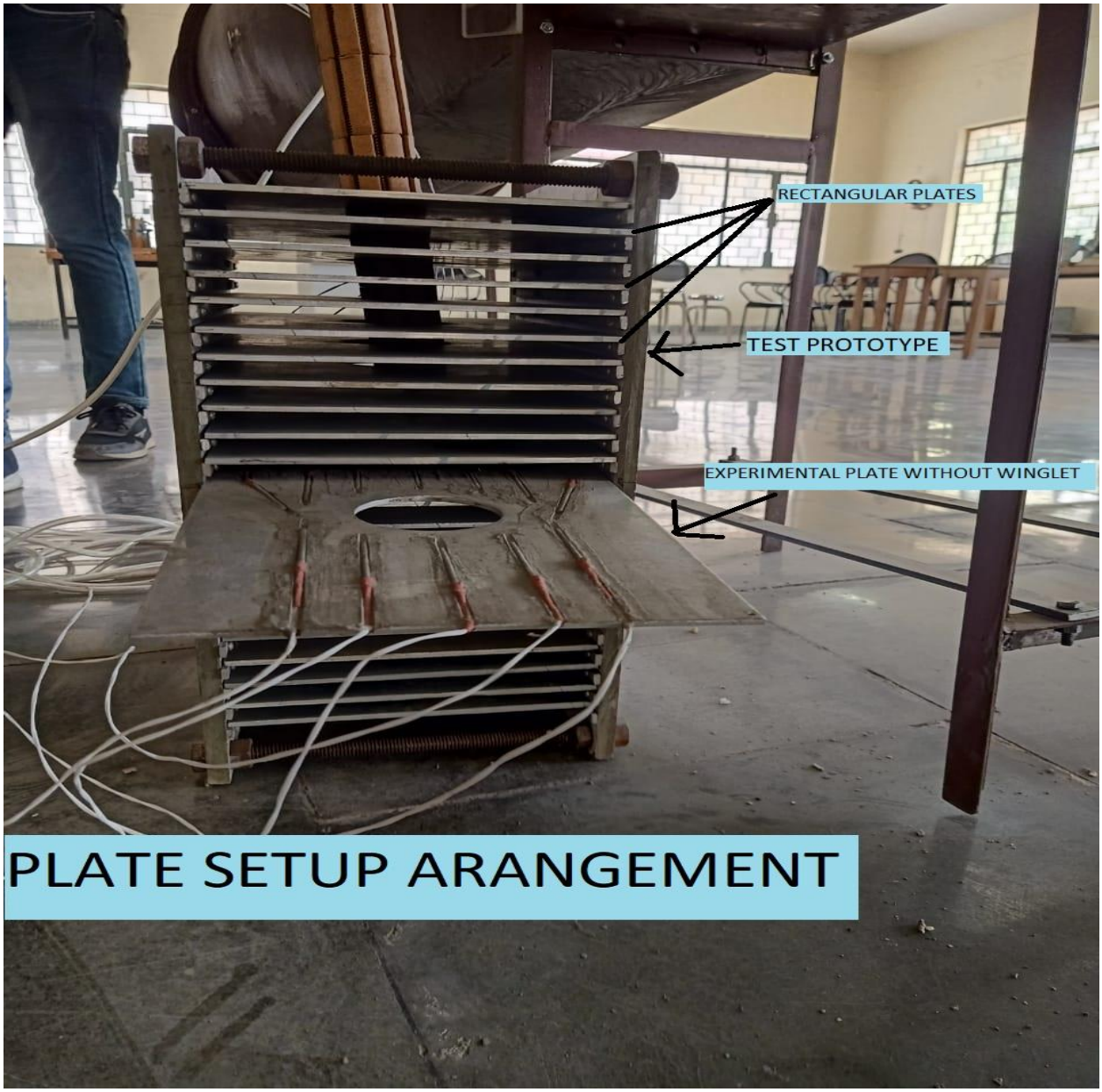


Figure 3 Experimental Plate Test Set Up

2.3 HEATER PLATE DIMENSIONS

The rectangular type heater is used for producing the heat to the mid experimental plate in this channel flow. The heater plate is 24 mm in length and 17 mm in breadth and 2 mm thick. It gives 300-watt power to the plate. Figure 4 shows the heater plate with experimental plate.

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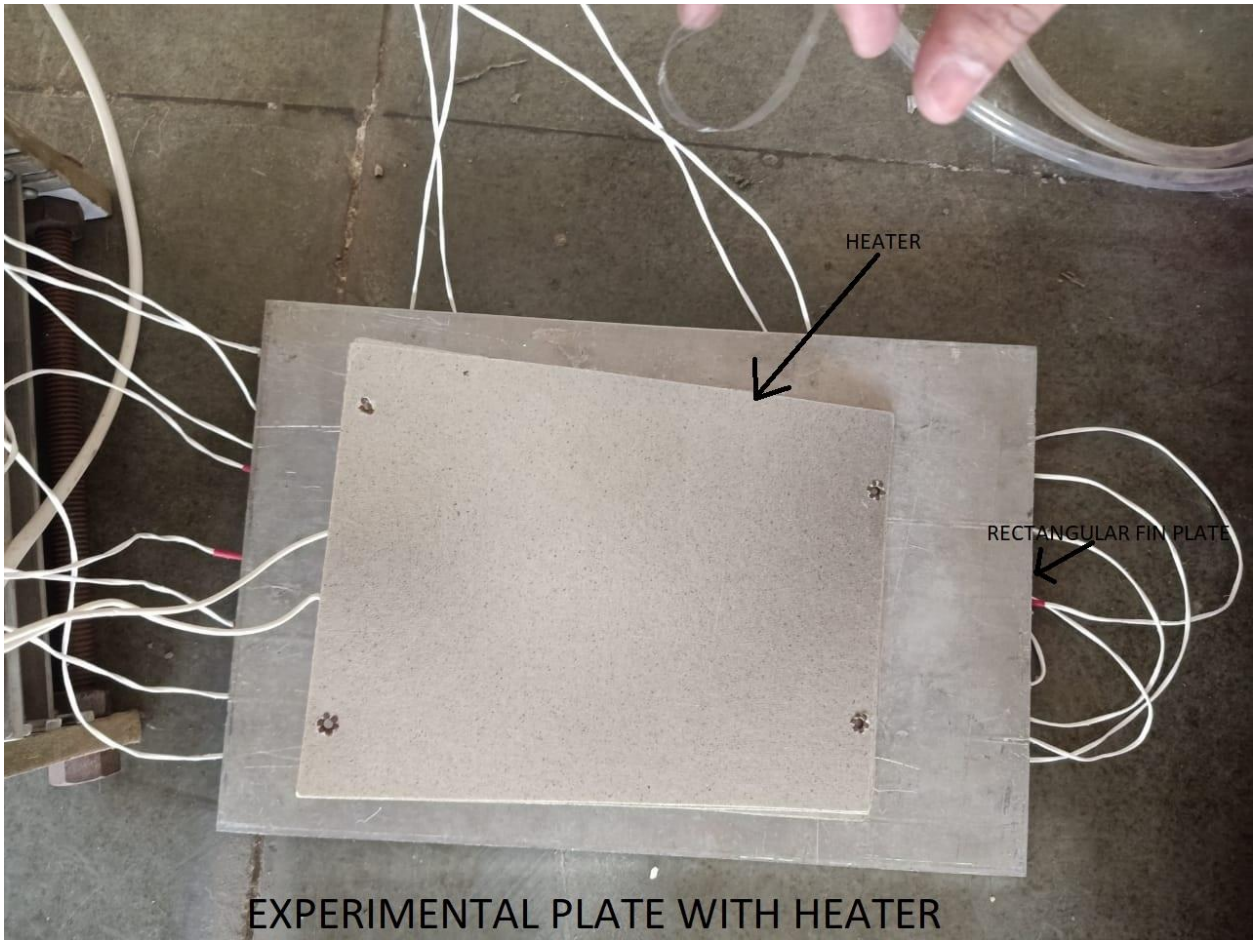


Figure 4: Heater Plate with experiment plate

2.4 DATA LOGGER

The data logger is used for recording all thermocouple temperature and pressure difference value on the screen. Although there are 12 thermocouples are fixed on plate where as one thermocouple is used where the air enters the plate and one is fixed where the air exits from the plate. Fan speed is also controlled and noted on the data logger. The data logger also contains the reading of the inlet air pressure and outlet air pressure. This record can contain directly in a pen drive or noted manually. Figure 5 shows the Data logger diagram.

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Figure 5: Data scanning logger

2.5 EXPERIMENTAL WORK

We want to measure the effect of the heat transfer rate on the rectangular fin plate with or without adjustment of the winglets. Firstly in our experiment work, only a simple rectangular fin plate without a winglet is used for finding the effect of rate of heat transfer. After that heat transfer rate is calculated on the rectangular fin plate with winglet and find the difference in between them. The thermo hydraulic efficiency/ performance evaluation criteria (PEC) represent the rate of heat transfer. So our primary focus is on calculating the value of PEC.

2.6 PROCEDURE FOR FINDING THE VALUE OF PEC OF RECTANGULAR PLATE WITH WINGLET

The Performance evaluation criteria (PEC) are calculated of the rectangular fin plate. Now we fit the modified delta winglet according to our objective on this rectangular fin plate for calculating the heat transfer rate/PEC. In the plate test setup, all 13 plates are arranged in a parallel way and this setup is fit on the throat. The 7th

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number mid plate is considered for measuring the heat transfer rate or finding the value of PEC. In this mid plate, the two modified delta winglets are fitted.Figure 6 shows the Experimental Plate with Winglet and Figure 7 shows the Test Section Experimental Plate with Winglet

The procedures below are used to determine the value of PEC from this experiment:

1. Attach the instrument's electrical supply to it.
2. At an angle, fix the winglet to the rectangular plate. In our experiments, we took three attack angles into consideration: 30, 45, and 60 degrees.
3. Turn on the heater and adjust its temperature to a preset value.
4. Start the fan and adjust its speed to meet the necessary air velocity requirements.
5. Hold off until the temperature fluctuations stabilize at a predetermined point, or wait for the steady state.
6. Insert the pen drive into the data logger so that temperature and pressure readings are automatically recorded at predetermined intervals of time.
7. Completing the reading on wind tunnel experiments begins with this stage.
8. Adjust the heater's air velocity, heat power, and attack angle in accordance with the specifications, then take another reading of the second reading.
9. Continue the experiment until all readings are collected in accordance with the specifications.
10. Using the same mathematical techniques as previously mentioned, determine the value of PEC based on these temperature and pressure measurements.

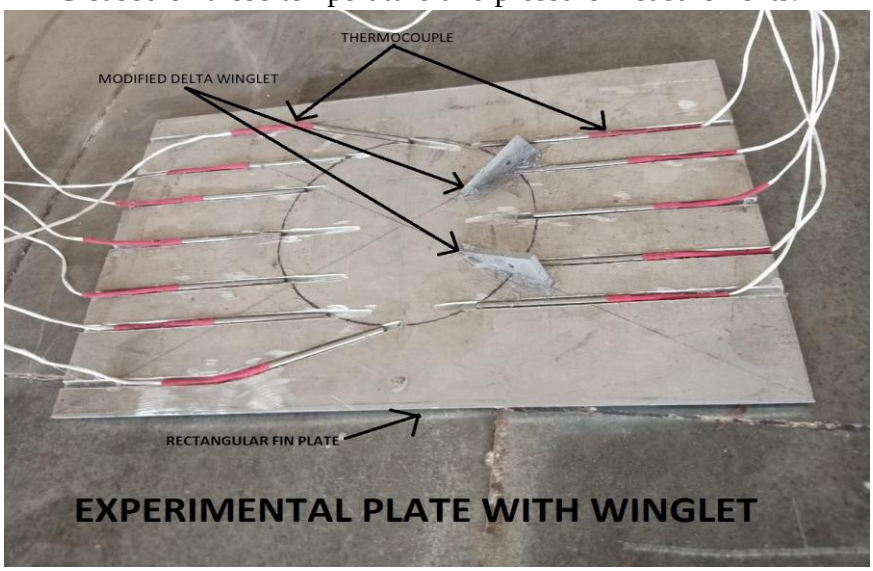


Figure 6: Experimental Plate with Winglet

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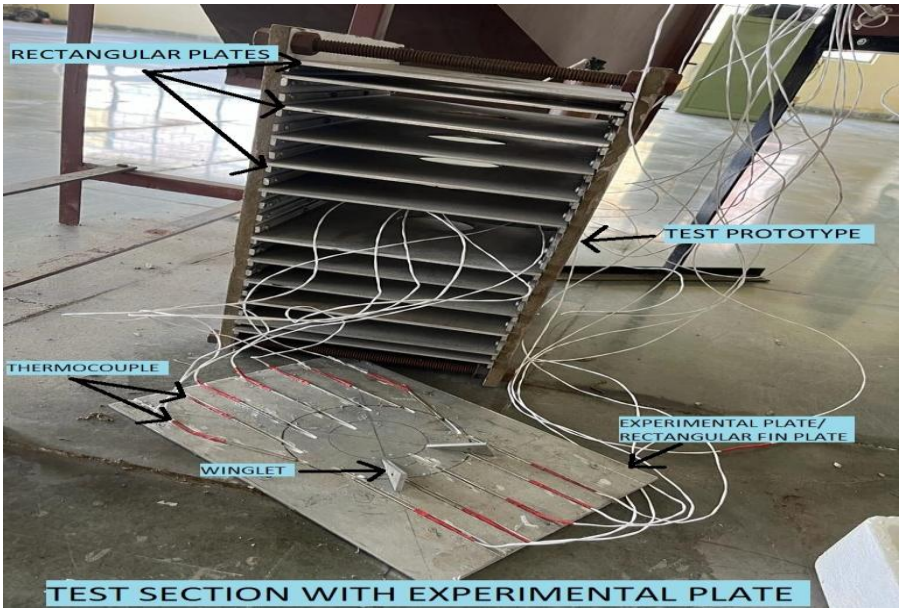


Figure 7: Test Section Experimental Plate with Winglet

2.7 EXPERIMENTAL RESULTS WITH WINGLET

The results are shown below in figures with using winglets. Figure 8 shows the Colburn factor with the Reynolds number. The value of the Colburn factor is lies between the 0.001086 to 0.004643. Figure 9 shows the friction factor with the Reynolds number. The value of the friction factor is lies between 0.009335 to 0.069357. The friction factor indicates the pressure drop. Figure 10 shows the Performance Evaluation Criteria (PEC) with the Reynolds number. The value of the PEC is lies between the 0.116377 to 0.066948. The PEC indicates the thermo hydraulic efficiency. Figure 11 shows the Colburn factor, friction factor and Performance Evaluation Criteria with Reynolds number in one diagram.

For calculating the final results; at each air velocity takes the 10 readings with modified delta winglet vortex generator (winglet); and after that find the average of this results calculate to make error free results. This calculation is also to be done with design a program on MS Excel software.

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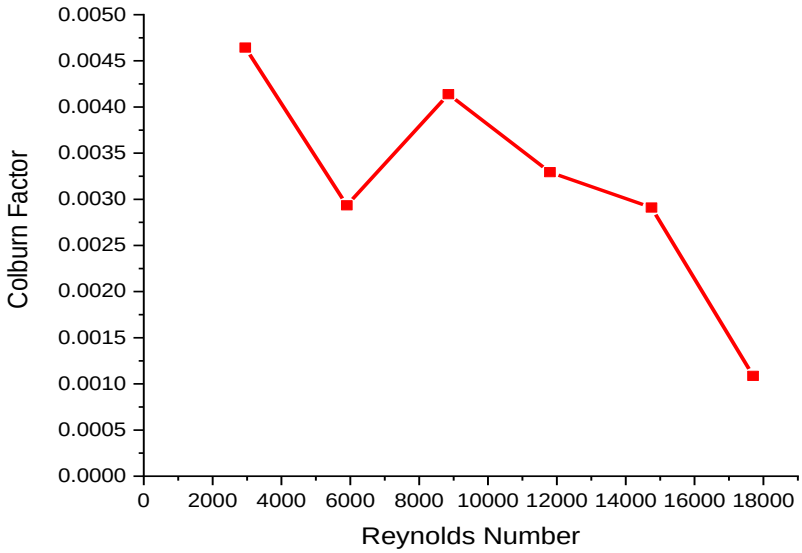


Figure 8: Colburn factor with Reynolds number

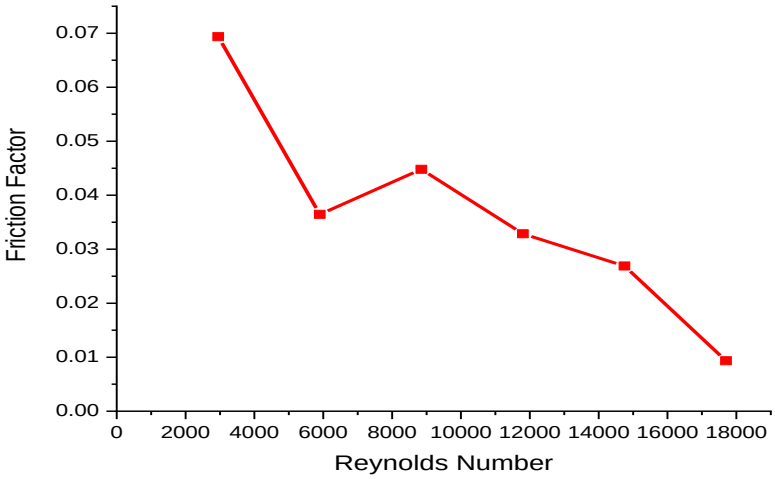


Figure 9: Friction factor with Reynolds number

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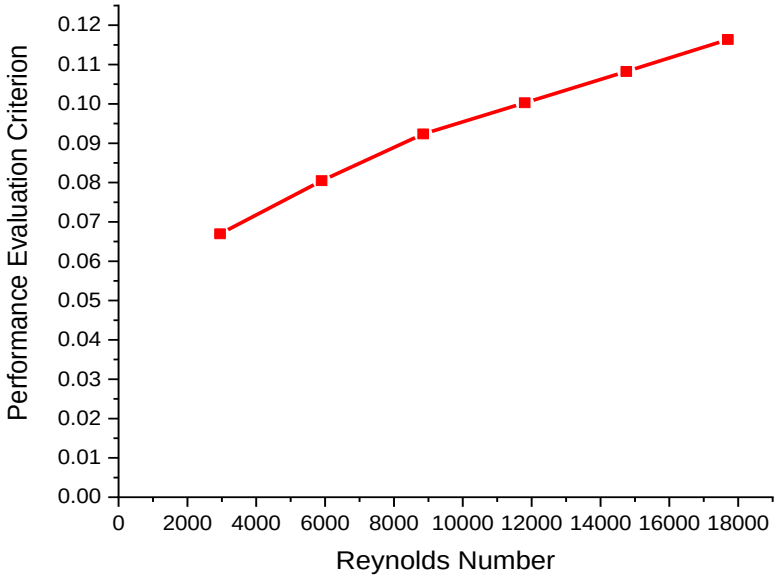
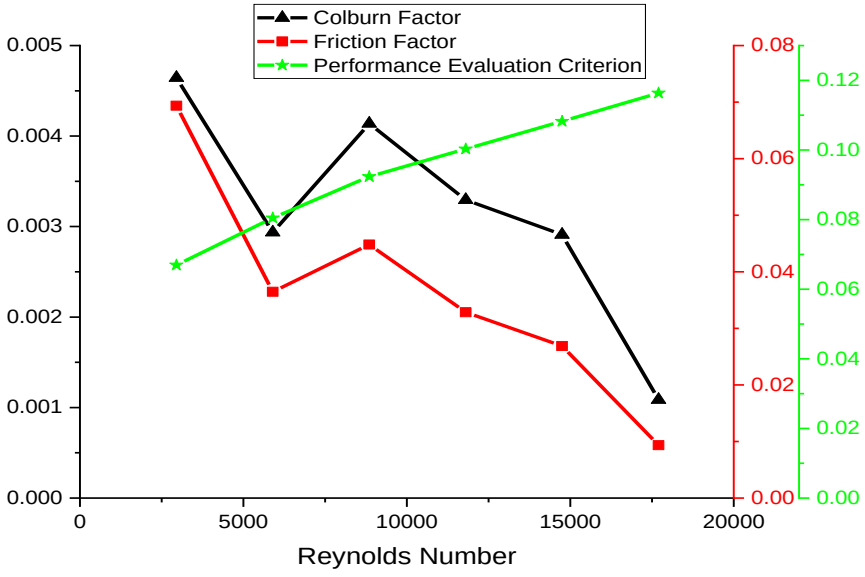


Figure 10: Performance Evaluation Criteria (PEC) with Reynolds number



. Figure 11: Colburn factor, Friction factor and Performance Evaluation Criteria with Reynolds number

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3. CONCLUSIONS

In this research, the Thermo hydraulic performance/ performance evolution criteria (PEC) of a modified delta fin plate in a channel flow are augmented by using the response surface method (RSM). RSM helps optimize the extracted performance evolution criteria to achieve practical specification goals. There are the following conclusions are obtained from the above research.

1. The heat transfer enhancement is obtained where as the pressure drop reduction and also found that the PEC is increased according to our objectives.
2. When the air velocity increases, the PEC also increases constantly. Only a slight change occurs when the heat power rises in the PEC.
3. While the attack angle increases, the PEC also increases at a level but approximately mid-level. Further, when the attack angle increased, the PEC decreased.

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THE EVOLUTION OF CONVENTIONAL SUPPLY CHAIN TOWARDS SMART, INTERCONNECTED, AND INTELLIGENT SUPPLY CHAIN

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Abstract

The contemporary landscape of supply chain management is experiencing a paradigm shift from traditional, linear models towards dynamic, interconnected, and intelligent systems. This research paper explores the evolution of supply chains, delineating the trajectory from conventional methodologies to the emergence of smart, interconnected, and intelligent supply chains. It delves into the technological advancements, organizational strategies, and transformative practices that facilitate this evolution, analysing the implications for businesses in the global marketplace.This paper explores the evolution of conventional supply chains towards smart, interconnected, and intelligent models, analysing the key drivers, disruptive technologies, and potential benefits and challenges associated with this shift.It aims to provide a comprehensive definition and explore how supply chain management has evolved over time.

Keywords

Smart supply chain, interconnected supply chain, intelligent supply chain, digital supply chain, Industry 4.0, Internet of Things, Big Data, Artificial intelligence.

Introduction

The globalized business landscape necessitates efficient and agile supply chains to meet diverse customer demands and navigate dynamic market conditions. Traditional supply chains, often characterized by linear structures, limited data visibility, and manual processes, are struggling to keep pace with the evolving business environment. This has led to the emergence of a new paradigm: the smart, interconnected, and intelligent supply chain.

This paper examines the evolution of conventional supply chains towards this more advanced model. It delves into the key drivers, including technological advancements, changing customer demands, and increased competition, that are fuelling this transformation. Additionally, the paper explores the role of disruptive technologies, such as the Internet of Things (IoT), Big Data, and Artificial Intelligence (AI) in enabling intelligent decision-making, real-time visibility, and

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automated processes within the supply chain.

Overview of traditional Supply chain

Supply chain management has gained significant traction since the 1980s. Companies have increasingly recognized the benefits of collaborative relationships, leading to a surge in interest in supply chain management practices[1]. The companiesaim to build a network of suppliers to establish a interconnected relationship that can lead to mutual benefits in terms of efficiency, cost and innovation. Also, the companies are facing the intense competition that need to optimise their overall performance.It enables the combined administration and control of information, funds, and material flows, enabling a new generation of manufacturing and distribution systems.The supply chain orchestrates departments like procurement, production, and logisticsto transform raw materials into end products[2].Numerical researchers define supply chain management (SCM) based on supply chain theories. SCM manages a complex supply chain network to deliver products and services to end-users efficiently and cost-effectively[3].Certainly, the conventional supply chain models laid the foundation for modern supply chain management but were associated with specific characteristics, limitations, and challenges.

Characteristics of Conventional Supply Chain Models

Linear Structure: Traditional supply chains operated as linear sequences of stages, starting from raw material procurement to manufacturing, warehousing, distribution, and ending with the customer.

Silos and Limited Visibility

Each stage often functioned independently, with limited communication and information flow between different components of the supply chain. Siloed operations hindered overall visibility and coordination.

Forecast-Driven

These models heavily relied on demand forecasting based on historical data to predict future demand patterns. This approach often led to challenges in accurately gauging unpredictable market changes.

Inventory Buffering

To manage uncertainties in demand and supply variations, companies maintained larger inventory buffers at various stages. However, this led to increased holding costs and tied up capital.

Supplier-Centric Approach

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The relationships with suppliers were primarily transactional, focusing mainly on cost reduction. Strategic partnerships or collaboration for mutual benefits beyond cost efficiency were less common.

Limitations and Challenges

Lack of Agility

Conventional supply chains were less agile and adaptable to sudden changes in customer demand or market conditions due to their linear and rigid structures.

Inefficient Inventory Management

Over-reliance on forecasts often resulted in either excess inventory (leading to increased holding costs) or shortages, impacting customer satisfaction.

Limited Visibility and Responsiveness

Lack of real-time data and information sharing among supply chain partners led to reduced visibility, making it challenging to respond promptly to disruptions or changes in demand.

Risk of Disruptions

The linear and siloed nature of these models made them vulnerable to disruptions—be it natural disasters, supplier issues, or sudden shifts in consumer behaviour.

Higher Operational Costs

Holding excess inventory, inefficient processes, and limited technology integration often increased operational costs.

Customer Service Challenges

Inflexible supply chains often struggled to meet changing customer expectations regarding speed, customization, and reliability. Various supply chain, evolvedto overcome challenges in traditional supply chain, are Green Supply Chain (GSC), Agile Supply Chain (ASC), Sustainable Supply Chain (SSC) and Digital Supply Chain (DSC). The key performance indicators and the focused dimensions for various supply chain evolved over the time period is shown in table 1.

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Table 1:Key Performance Indicators and Focused Dimensions for Various Supply Chain

S.N.	Supply Chain	Key Performance Indicators	Key Focus Dimensions
1	Traditional Supply Chain	Product driven, Inventory turns and Production cost, Production capacity coordination with suppliers	Focused on maximising economies of scales by using particular practices.
2	Green Supply Chain	Carbon Footprint, Energy consumption, Water Usage, Circular economy	Focused on Environmental Dimensions to reduce carbon emission.
3	Sustainable Supply Chain	Economic value created per unit of environmental impact, compliance with fair labour standards, social impacts of a product throughout its lifecycle	Focused on Social dimension as well as Environmental Dimensions
4	Agile Supply Chain	Customer driven, Value added, Lead time, Supplier Responsiveness towards change in demand	Focused on adaption to disruption
5	Digital Supply Chain	Data driven, Real-time communication, Business intelligence, transparency and traceability, data driven intelligent decision making	Focused on to integrate the digital technology to make more responsive as well as efficient supply chain

Green Supply Chain (GSC

Initially, traditional supply chain management prioritized cost, efficiency, and product variety, often neglecting environmental impacts. However, evolving environmental regulations have compelled manufacturers to consider not just process-related consequences (like taxes), but also the financial gains from reusing, recycling, reverse Logistics and reintroduce of product components[4]. The concept of GSC is emerged to fulfilling the environment regulations throughout the whole product lifecycle. The evolution of Green Supply Chain Management (GSCM) reflects the incorporation of environmental thinking in response to the rising need for environmental compliance [5].In order to decrease carbon emissions, corporations need to restructure their supply chain networks (SCNs), engage in a low-carbon system, and implement energy-efficient practices. The government also make the policy on carbon emission reduction which enforce the organisations to develop the green supply chains (GSCs). The study is also done on the three dimensions carbon tax, carbon cap, and carbon trading in GSC [6].

Sustainable Supply Chain (SSC)

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Sustainable development has come into the spotlight as a result of mounting environmental and climate change concerns, as well as conflicts stemming from socioeconomic disparities and destitution[7].With time it becomes essential to consider the social and environment concerns in the supply chain to achieve the sustainability. Due to impact of climate change the world is looking to reduce carbon emission and the supply chain has to shift towards green supply chain and sustainable supply chain. In the past, SCM prioritised optimising economies of scale through the adoption of specific procedures to satisfy stakeholder demands, completely disregarding social and environmental considerations in the process. An SSC is designed in such a way to have minimum negative impact on environment as well as on society and also focus on the maximum economics[8]. It puts the environment responsibility which includes minimizing resource depletion, pollution, and greenhouse gas emissions throughout the supply chain and social responsibility which includesensuring fair labour practices, ethical sourcing, and respect for human rights across all stages of production and economic responsibility which includesbalancing long-term economic viability with environmental and social considerations. Sustainable supply chain management is a crucial element for attaining a competitive edge in global markets. This approach seeks to streamline resource consumption by leveraging circular economy principles. It operates on a moral compass, guiding every participant in the chain on nurturing value and fostering reciprocal relationships to sustainably thrive[9].Beyond managing financial, information, and product flows, sustainable supply chain management seamlessly integrates social and environmental considerations within and across the chain, aiming for holistic optimization [10].

Agile Supply Chain (ASC)

As traditional Supply chain focused of economic efficiency, the Agile Supply Chain focuses on developing a responsive supply chain which is able to adapt quickly to changes in supply or demand. Achieving this entails fostering robust communication and collaboration within the supply chain network while embracing adaptability in processes and technology. It is also emphasizing flexibility in supply chain operations which enables to adapt changes and prowess to rapidly cater to evolving consumer demands for its products [11].Manufacturers are forced to develop agile supply chain skills to remain competitive due to evolving client demands and technological advancements. Consequently, numerous organisations are emphasising the importance of adaptability and responsiveness to promptly address the distinct requirements of clients and marketplaces[12].Many researchers have proposed the framework for the agile supply chain to asses the agility in the supply chain. The pressure of external environment on the ASC acts as driver for providing strengthen against the global competitiveness and improve their business performance and the information sharing using IT technology and some structural tools and techniques enables the supply chain to adapt the changing market conditions [13].

Digital Supply Chain (DSC)

In recent years the technological advancement occurs at faster rate and some very cutting-edge

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technology e.g. Big Data Analysis (BDA), Blockchain Technology (BT), Machine Learning (ML), Deep Machine Learning (DML), Artificial Intelligence (AI), Cloud Computing (CC) are evolved[14]. The COVID-19 crisis,postpandemiceconomic effects, and the ongoing conflict inUkraine have exposed thevulnerabilities of today'sglobal supply chains[15]. They have also made heroes ofthe teams that keep products flowing in a complex,uncertain, and fast-changing environment.Supplychain leaders now find themselves in an unfamiliarposition: they have the attention of topmanagementand a mandate to make real change.The organisations whether it is big or small are forced to integrate these digital technologies in the
supply chain to mitigate the risks and challenges faced due to disruption. This has led to the emergence of a new paradigm shift towards digital supply chain which is a smart, interconnected, and intelligent supply chain[16]. The adoption of industry 4.0 technology enables the SC managers to monitor constantly the product and provide the real time information throughout the whole product lifecycle[17].The Centre for Global Enterprise defines Digital Supply Chain (DSC) as 'a customer-centric platform model that captures and maximizes utilization of real- time data coming from a variety of sources. It enables demand stimulation, matching, sensing, and management to optimize performance and minimize risk'.

Drivers of the Evolution

While traditional supply chains were effective in their time, their limitations in adaptability, responsiveness, and agility have driven the need for the evolution toward smarter, interconnected, and intelligent supply chain models. This evolution aims to address these limitations by leveraging technology, data-driven decision-making, and collaborative networks to create more efficient, resilient, and customer-centric supply chains.Several key drivers are pushing conventional supply chains towards smart, interconnected, and intelligent models:

Technological Advancements

The rapid development of technologies like IoT, Big Data[18], blockchain technology [19], Machine Learning and AI[20] has revolutionized the way supply chains operate. Sensors embedded in products and equipment provide real-time data on location, condition, and usage, enabling greater visibility and proactive management. Big Data analytics unlock insights from massive datasets, allowing for predictive maintenance, demand forecasting, and optimized resource allocation[21].Data-driven technologies can be used to identify new market opportunities and develop innovative products and services that cater to specific customer needs, giving an edge in a crowded market.

Changing Customer Demands

Customers today demand faster delivery times, greater product customization, and enhanced visibility into the origin and sourcing of products[22].Digital platforms including e-commerce, social media, and mobile networks empower consumers to explore and purchase. They can customise their orders, buy them anytime, and get them in days.This necessitates a more flexible

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and responsive supply chain that can adapt to changing preferences and personalize offerings[23].Enhanced transparency and traceability through digital tools enable companies to build trust and loyalty with customers who are increasingly concerned about ethical sourcing and sustainability practices.

Increased Competition

Businesses face intense competition from global players, requiring them to constantly improve efficiency, reduce costs, and increase agility[24]. Smart supply chains offer a competitive advantage by enabling faster time to market, optimized inventory management, and reduced lead times. The competition act as like an important driver to invest in adoption the digital solutions to stay competitive and gain an edge.The dynamic nature of competitive environments pushes companies to constantly monitor, analyse, and improve their digital supply chains for sustained success. The organisations also seek to take competitive advantage by strengthening the supply chain capabilities and push themselves towards digital innovation[25].

Disruptive Technologies Enabling the Shift

Some of the disruptive technologies which enables the paradigm shift from traditional supply chain to smart supply chain are blockchain technology, internet of things, big data analysis, Artificial Intelligenceand machine learning(Fig. 1).

Blockchain Technology

The conventional approaches of supply chain management (SCM) are inadequate and unsatisfactory in maintaining transparency between suppliers and consumers.Traditional supply chains follow a sequence of events, beginning with the acquisition of raw materials and concluding with the distribution of final products. Blockchain technology enables the integration of smart contracts into supply chains, which in turn involve certifiers, registrars, and standards organisations[26]. Blockchain is an innovative data system that securely stores and documents comprehensive information related to a specific subject. It enables numerous stakeholders to comfortably collaborate and access the same data and information.supply chains more transparent and traceablethrough blockchain technology[27].The many researchers have done study on achieving the sustainability in supply chain with application of blockchain technology[28].

Machine Learning

Machine learning (ML) is transforming supply chain management by enabling predictive analytics, optimization, and automation. ML applications in the supply chain continue to evolve, leveraging advanced algorithms like neural networks, reinforcement learning, and deep learning to handle complex decision-making processes. Integrating these technologies enhances efficiency, reduces costs, and improves overall supply chain performance.Machine Learning

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(ML), which focuses on creating and using algorithms for computers that can "learn" from their experiences[29]. The issue of uncertainty in decision making can be efficiently handle by machine learning. Machine learning can be able to handle the unstructured data set for the forecasting while traditional supply chain suffers from uncertainty due to not able to deal with this data.ML algorithms analyse historical data, market trends, and external factors to predict future demand more accurately.ML helps in identifying and mitigating potential risks in the supply chain and in optimizing warehouse layout, picking routes, and inventory placement[30].

Internet of Things (IoT)

Sensors embedded in products, vehicles, and infrastructure provide real-time data on location, condition, and usage, enabling automated tracking, predictive maintenance, and optimized logistics.The IoT has a profound impact on supply chain management by providing real-time visibility, data-driven insights, and automation. IoT devices and connected sensors provide end-to-end visibility across the supply chain. IoT devices and sensors in warehouses optimize processes such as picking, packing, and inventory management.The integration of IoT technologies in the supply chain provides a wealth of data that, when analysed effectively, leads to more informed decision-making, streamlined operations, reduced costs, and improved overall efficiency.

Big Data Analysis (BDA)

Advanced analytics tools extract valuable insights from vast datasets, enabling demand forecasting, risk mitigation, and improved decision-making across the supply chain.In recent years supply chain becomes a data-driven process that focuses on optimizing supply chain management by leveraging large volumes of diverse data to derive valuable insights and enhance decision-making processes[31]. The analysis of large volume data is used to optimize supply chain activities under given constraints and enhance the decision making [32].The supply chain ecosystem is made more agile and competitive through the use of big data analysis, which in turn improves decision-making, operational efficiency, and responsiveness to market changes.

Artificial Intelligence (AI)

AI algorithms automate repetitive tasks, optimize processes, and predict future trends, leading to increased efficiency, reduced errors, and improved decision-making.AI is one of the most advanced technologies that organisations must use to stay ahead of the curve, with the potential to revolutionise operations, decision-making, and overall efficiency.Artificial intelligence's incorporation into the supply chain has utterly transformed company processes. That this is merely the start is what makes it so fascinating. The potential applications of artificial intelligence in the supply chain are endless as we gaze into the future. Now more than ever, businesses can maximise productivity, optimise inventory levels, and estimate demand with pinpoint accuracy thanks to predictive analytics.Drones and autonomous vehicles are revolutionising logistics by allowing for safer, faster deliveries.Warehouses are seeing increased

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production and decreased expenses thanks to AI-driven robots.AI has the potential to revolutionise several industries because to its remarkable data analysis capabilities, intuitive relationship understanding, operational visibility, and capacity to aid in improved decision making.

Benefits of Smart, Interconnected, and Intelligent Supply Chains

Increased Efficiency and Productivity

Automating processes and leveraging data-driven insights lead to reduced waste, improved resource utilization, and increased production efficiency[33].Striking a balance between being efficient and responsive is pivotal. The ability to quickly respond to changing market conditions and consumer needs is what makes a supply chain responsive, while efficiency ensures cost-effectiveness and stability. To optimise efficiency and responsiveness based on the individual needs of an organisation and its market environment, smart supply chains attempt to achieve a balance between these two aspects by employing technology, data analytics, and flexible procedures.

Enhanced Visibility and Transparency

One of the most transformative aspects of smart supply chains is enhanced visibility and transparency. Real-time data tracking and integrated platforms provide end-to-end visibility into the supply chain, enabling proactive problem-solving and informed decision-making[34]. A QR code on a product box shows its full route from the farm where the raw materials were sourced to the facility where it was made. Logistics companies can follow their trucks in real-time to optimise routes and deliver on time. A manufacturer can monitor equipment performance and predict maintenance concerns before downtime. Thus

Improved Agility and Resilience

Smart supply chains can adapt to disruptions and demand changes quickly, minimizing downtime and mitigating risks[33].Automated workflows and intelligent algorithms in supply chain enables streamline operations and frees up resources to focus on strategic initiatives that enhance responsiveness and adaptability[35].The new technology e.g. AI can even predict the potential disruption by analysing the data and can identify any pattern or corelation that might give trouble. By anticipating disruptions, businesses can take preventive measures.

Personalized Customer Experience

Real-time data and AI-powered personalization enable flexible order fulfilment and customized offerings, enhancing customer satisfaction and loyalty[35].In a smart supply chain, personalized customer experiences are facilitated through various technologies and data-driven strategies.Real-time communication and serviceenhances transparency and keeps customers

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informed throughout the process.

Reduced Costs and Environmental Impact

Optimized resource allocation, waste reduction, and improved energy efficiency contribute to lower operating costs and a more sustainable supply chain[36]. Smart supply chain facilitates the retrieval and reuse of resources, so completing the cycle of materials and reducing waste to a minimum. the new technology like 3D printing has the capability to produce replacement components using recycled materials, hence decreasing the need for new resources. Optimal logistics and transportation routes reduce fuel usage and emissions of greenhouse gases.

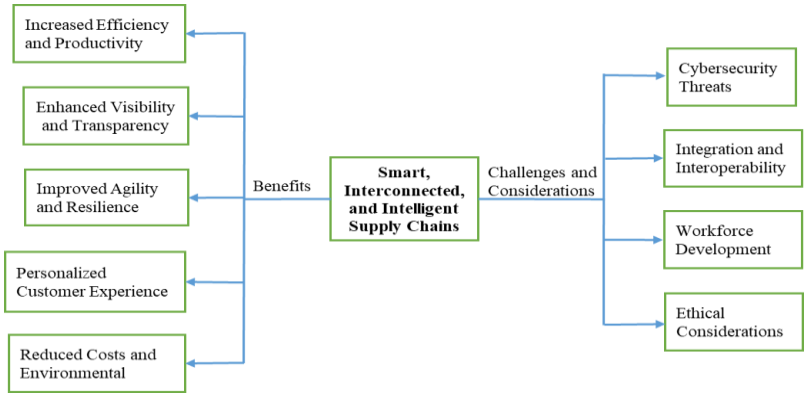


Figure 1: Benefits, Challenges and Considerations in Smart Supply Chain

Challenges and Considerations

Cybersecurity Threats

Increased connectivity introduces vulnerabilities to cyberattacks, necessitating robust cybersecurity measures and data encryption protocols[37]. Data breaches, ransomware attack can disrupt the supply chain operation and also can cause the financial losses. Attackers can get access to the larger supply chain network through vendors' or third-party service providers' weak cybersecurity safeguards.

Integration and Interoperability

The integration and interoperability issues in smart supply chains is related to the challenges of connecting various systems, technologies, and stakeholders inside the supply chain ecosystem. Integrating diverse systems and technologies across the supply chain requires standardized protocols and data exchange formats[38].Integration allows different components, including as software programmes, databases, IoT devices, and platforms, to collaborate and share information in real time.Integrating these disparate systems to communicate and work seamlessly poses a significant challenge.

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Workforce Development

The shift towards automated processes requires upskilling and reskilling initiatives to equip workers with the necessary digital competencies[35].Technology advances quickly, so smart supply chain operations require ongoing training to keep employees up to date.A diverse skill set is necessary for smart supply chains, combining traditional supply chain capabilities (like logistics and inventory management) with technical competence (like data analysis and IoT proficiency). It can be difficult to develop talent with this mix of abilities.

Ethical Considerations

Data privacy concerns and potential biases in AI algorithms require transparent data governance and ethical AI frameworks[38].Staff members or insiders with possession of sensitive supply chain data might undermine security either deliberately or unintentionally through actions such as data theft or unintentional dissemination.

Conclusion

The evolution of conventional supply chains towards smart, interconnected, and intelligent models signifies a paradigm shift in the way businesses operate. While challenges exist, the potential benefits of this transformation are substantial, paving the way for increased efficiency, an improved customer experience, and greater competitiveness. According to McKinsey's "Supply Chain 4.0—the application of the Internet of Things, the use of advanced robotics, and the application of advanced analytics of big data in supply chain management—place sensors in everything, create networks everywhere, automate anything, and analyse everything to significantly improve performance and customer satisfaction." Cutting-edge technologies like AI, robotics, and big data will revolutionize how we manage goods and materials through a smart, interconnected, and intelligent supply chain. Experts predict that businesses will experience a significant impact in the next few years, including dramatic cost reductions of up to 30%. That's the kind of efficiency boost Smart Supply Chain promises. Automation, smarter logistics, and optimized workflows will be the key drivers, freeing up resources and boosting profitability. Lost Sales Plummeting: Kiss those frustrating "out of stock" notices goodbye! By potentially reducing lost sales by 75%, businesses can ensure their shelves are always stocked with the right products at the right time. Real-time inventory tracking and demand forecasting will be the game-changers here. Leaner inventories, which means that Supply Chain 4.0's magic touch can shrink inventories by up to 75%, Just-in-time deliveries, precise production planning, and circular economy principles will work together to minimise waste and optimize storage space. Supercharged Agility: Forget clunky, inflexible supply chains. Supply Chain 4.0 injects a dose of lightning-fast agility, enabling businesses to adapt to market shifts, respond to disruptions, and seize new opportunities on the fly. This will be crucial in today's dynamic and unpredictable business landscape. By embracing this technological integration with the supply chain, businesses can unlock a future of enhanced competitiveness,

higher profits, and a more sustainable way of doing business.

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INFLUENCES OF COMPACTION PROCESS PARAMETERS ON MECHANICAL PROPERTIES IN HYBRID-FREEZE CASTING PROCESS

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Abstract

The main objective of this research paper is to identify the influences of process parameters compaction pressure, composition and the amount of additives, on the compressive strength by Genetic Algorithm optimization method. In Hybrid Freeze Casting Process, the compaction process has been added during the pouring process to enhance the compressive strength of castings. The scanning electron microscope (SEM) microstructures have been analyzed to evaluate the orientation and size of particles, additive bonding with particles and pore sizes.

Keywords

Compaction Pressure, Composition, Amount of Additive, Compressive Strength, SEM.

Introduction

In Ceramic Matrix Composites (CMCs), widely used reinforcing materials are carbon, alumina, silicon carbide, zirconium, Titanium, etc. The excellent properties of Ceramics Matrix Composites (CMCs) have identified as many industrial applications to work, efficiently. There are several applications of ceramic matrix composite like aerospace and automotive applications, bone implantation in the orthopedic department, petroleum hydrotreating, potential adsorbent in chemical warfare, solar cells, instruments to sense humidity, fabrication in electronics appliances, fabricating electrolyte for solid oxide fuel cell, extreme speed cutting tool purpose, structures for gas turbine engines, insulating materials for electrical and thermal purposes [1-12].

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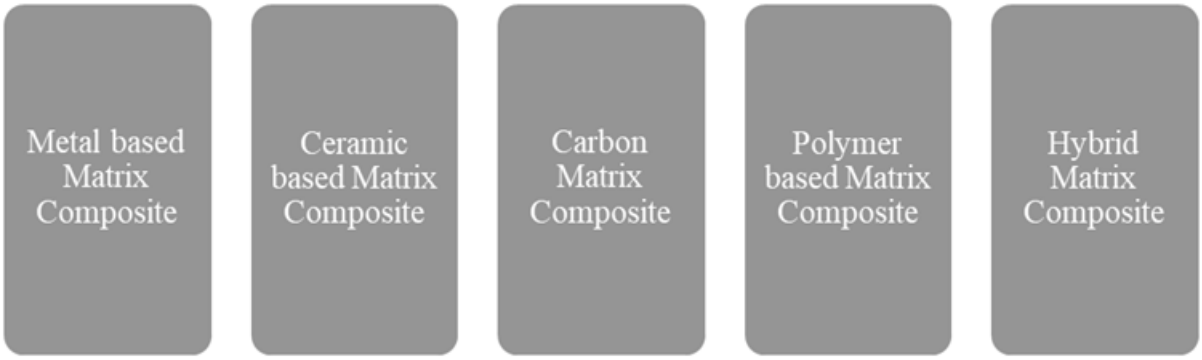


Figure 1. Classification of composites

Common properties of CMCs have high sustainability and resistance ability under high thermal shock, creep, corrosion, and wear loadings. It showed inertness to aggressive chemical compounds as well as high tensile and compressive strength, therefore no unexpected failure compared to traditional ceramics.

Literature Review

Pietrzykowska et al. [2021] performed the composition of 5wt% silk fibers with 15wt% nanocrystalline hydroxyapatite mixed it by cryomilling process compacted under a pressure of 1GPA at 80℃,obtained a homogeneous and dense ceramic matrix composite bar of dimension 4mm*4mm*35mm with excellent adhesion quality when interacted nano sized Hydroxyapatite with silk fibers, compressive strength and bending strength calculated as 276 MPa and 82 MPa for the composition 15wt% silk with 85wt% HAP, they achieved acceptable bending, compressive strength as well as modulus of elasticity which are similar to the real bone mechanical characteristics, the material which they achieved the appreciable applications in bone crack fillings and also they justify their result through SEM. **Li et al** [2021] used FDM technique for the fabrication of bone scaffolds by the help of PLA (Polylactic Acid) then coated with alginate composition of Hydroxyapatite by freeze-drying. Examined various sample for mechanical and biological nature and conclude that increasement in elastic modulus from 350MPa to 394MPa with 10 wt % HA nanoparticles, with decrement in porosity 44 % to 36 %, and with 30 wt% HA nanoparticles there is increment in compressive strength 25.2 MPa to 32.7 MPa. SEM and XRD used to study its morphology and phase characterization, and examined its porosity by ABAQUS technique, by seeing all results they conclude these data were good for development in bone substitutes.

Li et al. [2022], studied the module of inverse tangent on the cyclic loading and unloading nature of fiber-reinforced CMCs because under the cyclic loading/unloading mechanical hysteresis appears due to multiple micro damage mechanism, the micro damage analysis are identified by X-ray computed tomography and scanning electron microscopy. A micromechanical model is also developed based on the damage mechanism analysis. **Liu et al. [2020],** considered the tempering phase of CMCs, due to unique structure and excellent properties Nano carbon materials like carbon nanotubes, graphene, etc. They developed and reviewed the nanocarbon – toughened CMCs based on their properties and fabrication method of nano-carbon reinforced CMCs. This research stands towards the variation of the intersecting bonding positions, based on

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the properties of nanocarbon-reinforced CMCs.

Maillet et al. [2012] calculated acoustic emission energy while fatigue experiments on CMCs at different temperatures, and determine a characteristic time. The damage monitoring and life time prediction shows via. Coefficient of emission RK(n) technique and stress-induced damage nearly 10-20mm around rupture point by Optimum circle method using Benioff law. By the both methods they get to know the presence of detached phases on surfaces of CMCs while static fatigue test happens at different level of temperatures, first transformation phase indicates towards changes in interfacial and the second phase indicates the dominant. **Dassios et al. [2013],** investigated the mechanical properties related performance like thermal residual stress, cyclic loading and acoustic emission in the presence of notch for a SiC-fiber reinforced BMAS based CMCs. As compared with pure tension there is an increment by 20% on Cyclic loading result in the sustainable material stress. Thermal residual stress observed directly from the intersection point of cyclic data as 163 MPa which is favorable with theoretical TRS model, due to notch presence there is a formation of crack in matrixes and promotion of catastrophic failure.

Cao et al. [2015] investigated surface properties and forces in grinding process, by comparing between different surfaces. They conduct so many experiments and in detail they analyze the characteristics. With increment in grinding wheel speed there is decrement in surface topography height. **Wrenn et al. [2013]** manufactured composite by chemical vapor infiltration (CVI) method Silicon carbide with boron carbide used as matrix with reinforcement Hi-Nicalon™.Then at 1200℃ at 1.0 Hz they investigated the tension-compression fatigue behavior in both air and steam the fatigue stresses level ranges between 80-200MPa.At 80MPa there is no any reduction in tensile strength which shows there is no any damage presents. Tension–compression cycle shows more damaging behavior as comparable to tension–tension fatigue.

Servadei et al. [2022] fabricated C/UHTC composites by combining fabrication methods of CMCs like water-mixed in slurry, Polymer Infiltration Pyrolysis (PIP), as well as Hot Pressing (HP) methods to find the optimal integration technique for better integration of the carbon fiber fabrics into the super refractory ZrB2-SiC sintered ceramic matrix. Flexural strengths were calculated as 167 MPa at atmospheric temperature and at 1500 °C. 592 MPa were calculated and found to be slightly higher. **Ferrari et al. [2016]** fabricated a ceramic sandwich to withstand at a heat protection system consisting of a CMC bonded with a porous ceramic core. A feature of their work lies in the dual use. With the selected periodic porous ceramic design, the prototype was achieved through additive manufacturing and coupled with the CMC skin. Finally, a large-scale testing was conducted in a plasma-based wind tunnel and showed appreciated behavior. Hence, one approach we used to overcome from this problem is by using Ceramic Matrix Composite Materials with a matrix Nano-particle-Hydroxyapatite, having reinforcement material like:-ZrO_2 and Al_2O_3. Onto the surface of a biomedical implantation. Hydroxyapatite has a major role to accelerate bone in growth properties, and it have both chemically and mechanically properties which is familiar with bone.

Problem Formulation

Based on literature review, many problems have been observed while fabricating the ceramic matrix composites. Due to shortage in physicochemical bonding between HAP and the organic substance, mechanical properties will affect. At uniaxial pressuring process in freeze casting

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process, we must maintain the sufficient pressure and temperature, otherwise, it may affect our material and compressing die configurations. The sintering temperature must be maintained. The mixture should be uniformly mixed for better results.

Materials and Methods

For our research contribution, hydroxyapatite and Alumina were chosen as matrix and reinforcement materials to fabricate the ceramics matrix composites, through a unidirectional compression process. The experimental runs, at three different process parameters with their three considerable different levels, as shown in Table-1. Firstly, the mixture has been prepared with a defined composition of matrix and reinforcement with Polyvinyl Alcohol as a binder and glycerol as an additive. The prepared mixture has been compressed at three different compaction pressures and compaction holding times, with the help of the uniaxial compression process. After the compaction process, the specimens have been sintered in a muffle furnace at 1000°C. The experimental process and setup are described in figure-2. In order to study their structural analysis X-ray diffraction (XRD) is used and for microstructural and for surface morphology analysis we use scanning electron microscope (SEM) and elemental contribution analysis is done via Energy-Dispersive X-Ray Analysis (EDX).

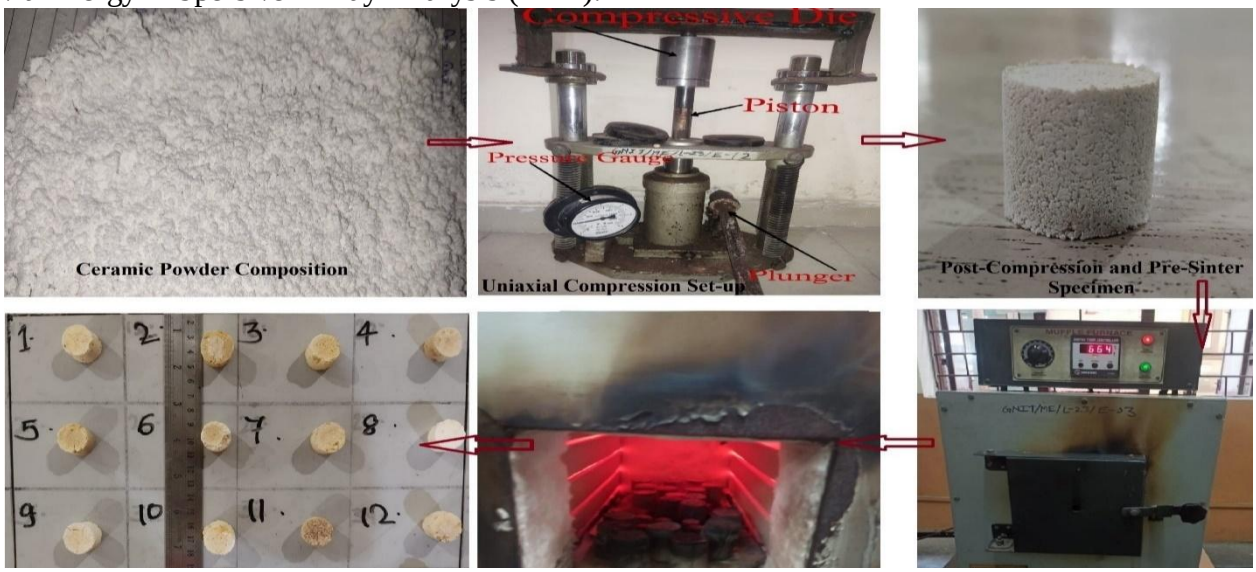


Figure 2. Experimentation of the manufacturing process of the specimens.

Table 1. Selected parameters with their three levels

Parameters	Level-1	Level-2	Level-3
Composition	Al_2O_3(0%) + HAp(100%)	Al_2O_3 (10%)+ HAp(90%)	Al_2O_3 (20%) + HAp(80%)
Compaction Force (kN/mm^2)	1	1.75	2.5
Compaction Time (min.)	10	20	30

Results and Discussions

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For characterization process we prepare total 9 samples by varying composition and for each level we prepare 3 sample by varying process parameters such as it's compaction Force and Compaction Time as shown in above Table-1.

EDX analysis

The other name of Energy–dispersive x-ray (EDX) analysis, is Energy Dispersive X-ray spectroscopy coupled with SEM is an analyzing technique which is used by researcher to calculate the chemical composition and elemental distribution that in what percentage the element is present in their sample. For our sample analysis first up all we mount our sample on an aluminum stubs with the help of adhesive conducting carbon tape then a sputter coating is required for our ceramic sample to make it conducting by Polaron SE7640 then observed via(SEM) Carl Zeiss EVO 40 (Cambridge, UK) for studying microstructure behavior and for EDX with a Bruker X-Flash Detector 3010 (Germany) operating at 20kv. In order to confirm the formation of HAp and (Al_2O_3 – HAp) nanoparticle composites EDX analysis was performed. Different area of specimen was focused during analysis and the corresponding peaks.

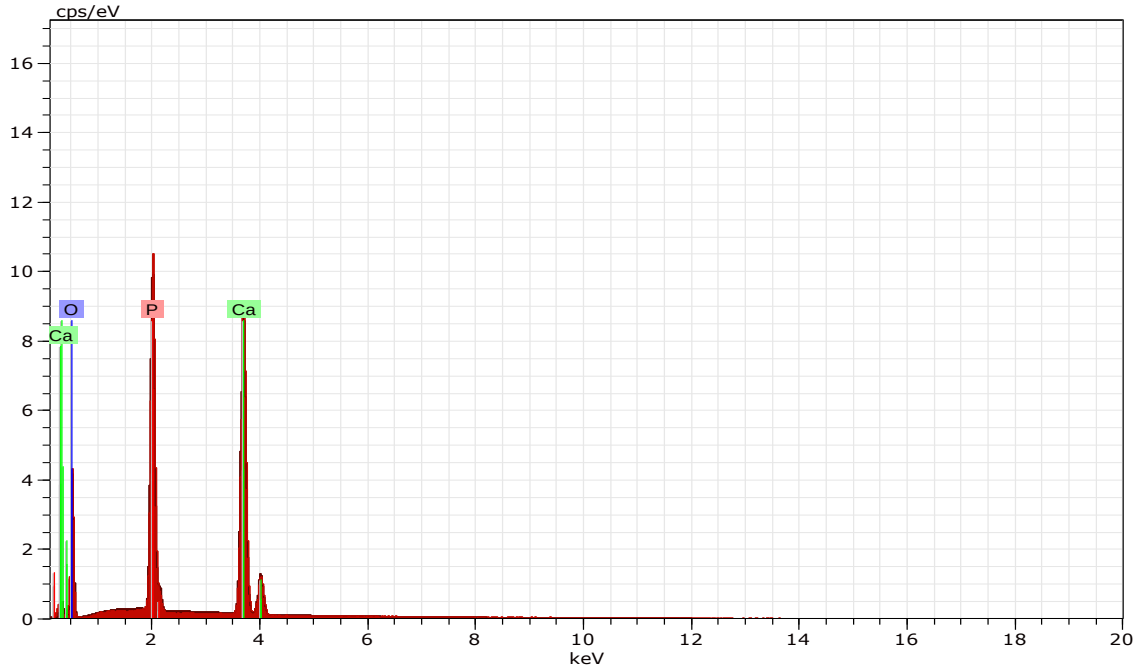


Figure 3(a):-Spectrum-1 for composition Al_2O_3(0%) + HAp(100%) at 1KN for 10min compaction time.

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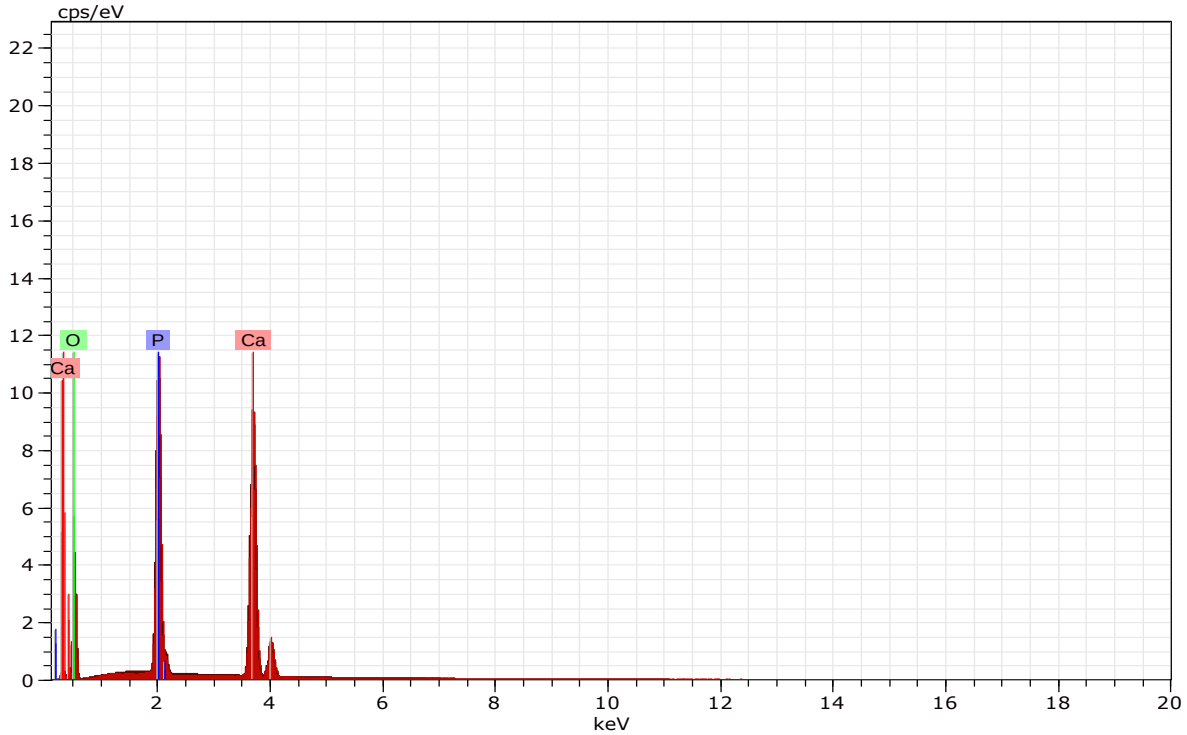


Figure 3(b):-Spectrum-2 for composition Al_2O_3(0%) + HAp(100%) at 1.75KN for 20min compaction time.

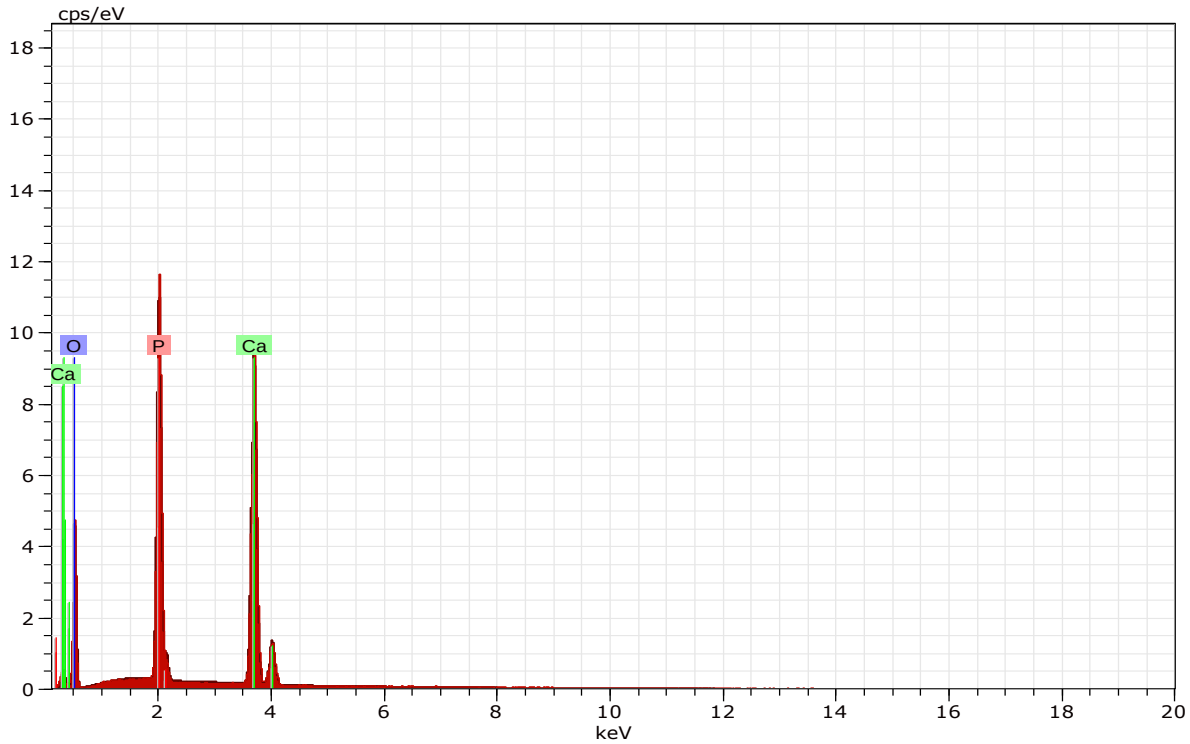


Figure 3(c):-Spectrum-3 for composition Al_2O_3(0%) + HAp(100%) at 2.5KN for 30min compaction time.

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The spectrum-1 is an elemental distribution for HAp ($Ca_{10}(PO_4)6(OH)_2$), the quantity measured in atomic % of Ca,P and O are 16.48,12.80 and 70.72 respectively while in spectrum -2, the values are 17.22,13.64 and 69.14 respectively and in spectrum-3,the quantity measured is 16.65,13.56 and 69.79.The details of these 3 EDX analysis of nanocomposite HAp in atomic and weight percentage is listed in below Table-2.

Table 2: Composition of Elements

Al_2O_3(0%)+HAp(100%)composite	**Calcium**		**Phosphorus**		**Oxygen**	
	Wt. (%)	Atomic (%)	Wt. (%)	Atomic (%)	Wt. (%)	Atomic (%)
Spectrum-1	30.18	16.48	18.12	12.80	51.70	70.72
Spectrum-2	31.11	17.22	19.04	13.64	49.85	69.14
Spectrum-3	30.28	16.65	19.05	13.56	50.67	69.79

The below Figure-4 is for composition Al_2O_3 (10%)+HAp (90%) for different process parameters:-

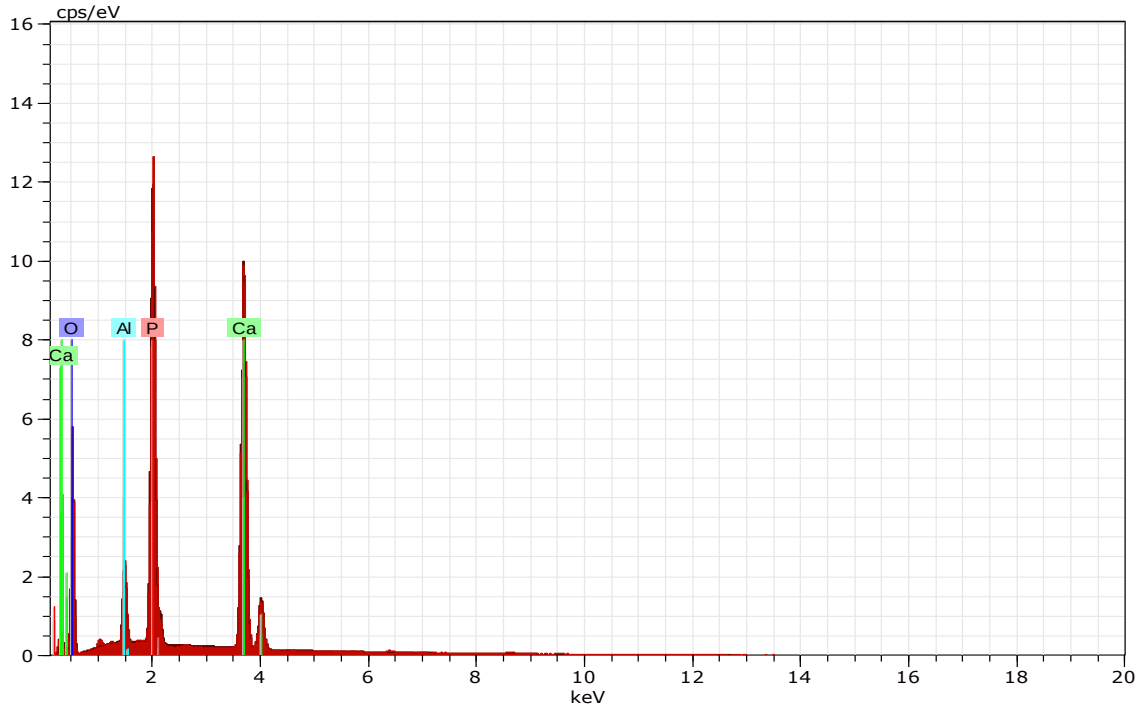


Figure 4(a):- Spectrum-4 for composition Al_2O_3(10%) + HAp(90%) at 1KN for 10min compaction

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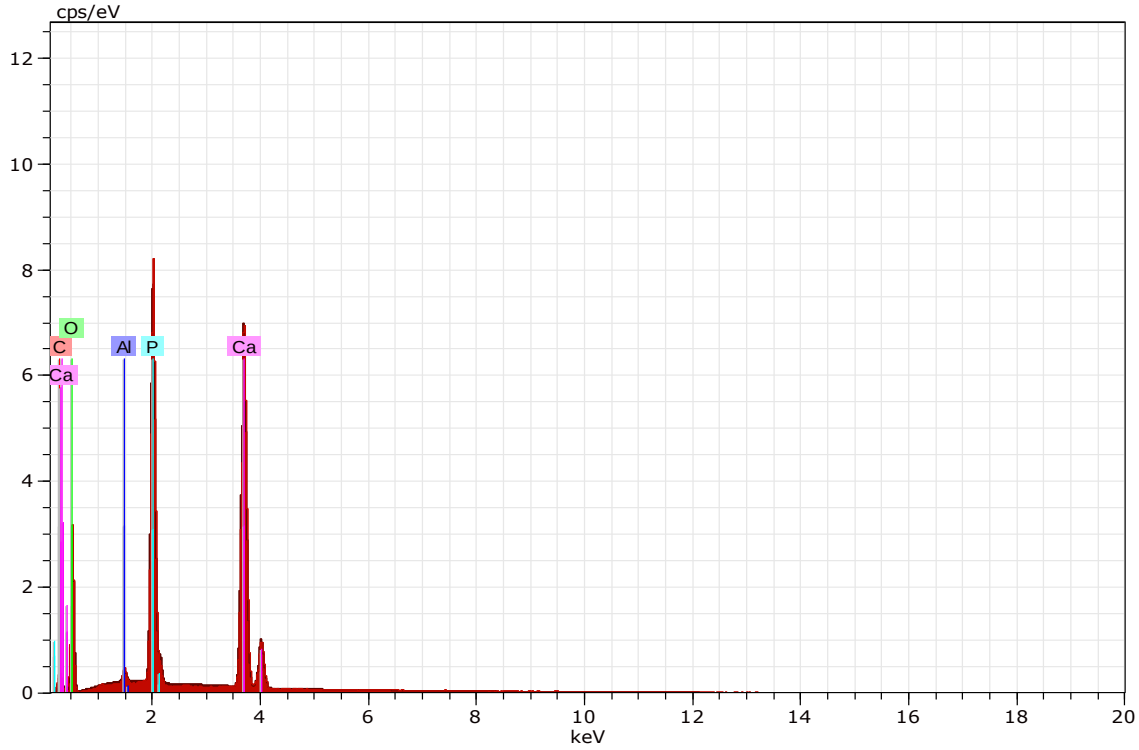


Figure 4(b):- Spectrum-5 for composition Al_2O_3(10%) + HAp(90%) at 1.75KN for 20min compaction time.

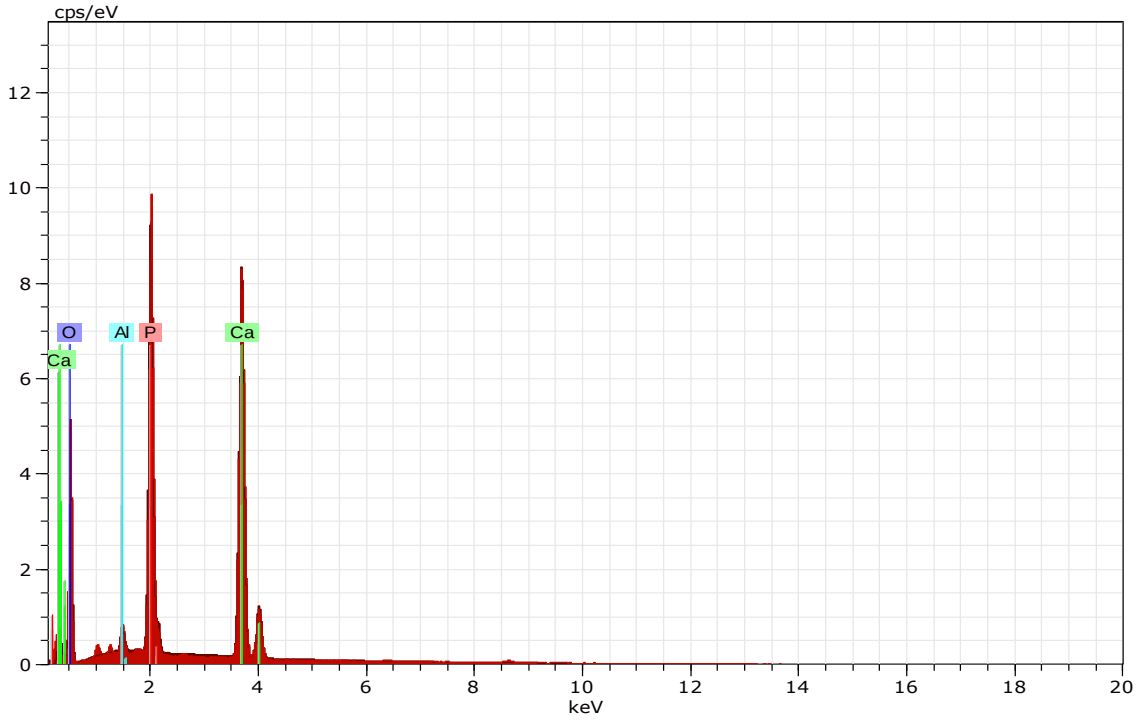


Figure 4(c):- Spectrum-6 for composition Al_2O_3(10%) + HAp(90%) at 2.5KN for 30min compaction time.

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The details of these 3 EDX analysis for nanocomposite (HAp- $Al_2O_{3)}$ in atomic and weight percentage is listed in below Table-3.

Table 3: Composition of Elements

Al_2O_3(10%)+ HAp(90%)composite	Calcium		Phosphorus		Oxygen		Aluminum	
	Wt. (%)	Atomic (%)	Wt. (%)	Atomic (%)	Wt. (%)	Atomic (%)	Wt. (%)	Atomic (%)
Spectrum-4	27.16	14.69	18.11	12.68	51.91	70.36	2.82	2.27
Spectrum-5	29.76	16.07	18.01	12.59	49.78	67.35	0.43	0.35

By seeing all the analysis, it can prove that there is no any impurities present in our specimen.

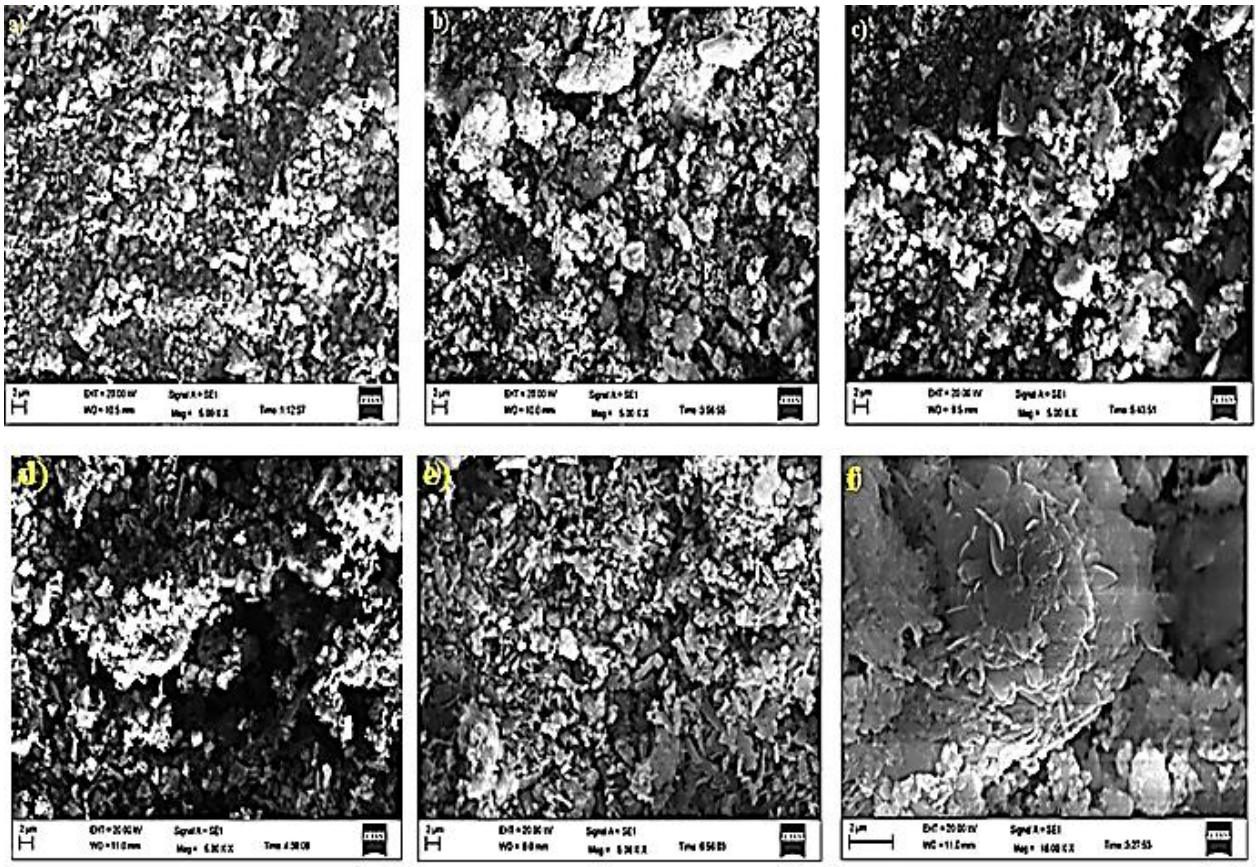


Fig.-4: SEM micrography at a) 20 nm HAp particle size and 14% alumina, b) 60 nm HAp particle size and 28% alumina and c) 20 nm HAp particle size and 20% alumina, d) 55% solid loading and 1150 °C sintering temperature, e) 65% solid loading and 1250 °C sintering temperature and f) 45% solid loading and 1350 °C sintering temperature.

Scanning Electron Microscope (SEM) Microstructure

The effects of most significant process parameters like particle size, amount of reinforcement, solid loading and sintering temperature on microstructure have been analyzed as shown in figure

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4 a) to 4 f). It has been observed that as the particle size of matrix HAp increases, the average pore size and porosity increase, which generates a denser and more compact microstructure. At 20 nm particle size, the average pore size increased up to 100 µm and its value increased up to 300 µm for 60 nm particle size. It has been found that a larger amount of reinforcement alumina of 200 nm increases the compressive strength of the specimens because the uniform distribution of alumina acts as the load carrier. The solid loading and sintering temperature are the most affecting process parameters to increase compressive strength and hardness. The porosity and pore sizes decreased when the solid loading and sintering temperature increased, So, the microstructure becomes denser and more compact. The reason behind this result is that large solid loading means a small amount of solvent. A small amount of solvent produced fewer dendroids and lamellar ceramic structures. The cellular and columnar microstructure have been observed at 55% of solid loading. At a higher sintering temperature of 1350 °C, the microstructure becomes denser because the particles produced better compacting and bonding with adjacent particles and partially plasticity nature at high heat transfer.

Future Scope

Onto the surface of a biomedical implantation Hydroxyapatite has a major role to accelerate bone in growth properties, and it have both chemically and mechanically properties which is familiar with bone. It has been observed as just like mineral section of bones as well as hard tissues in well-advanced productions. Its physical as well as chemical characteristics are highly applicable and like composition as of bones of human and dental tissues. It is most appropriate biocompatible, biodegradable and bioactive substances that increase bone in-growth.

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CERAMIC MATRIX NANOCOMPOSITE IN BIOMEDICAL AND DENTAL APPLICATIONS -A REVIEW

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Abstract

Nanocomposites are playing an important role in the areas of medicine, biology and electronics. In biomedical and dental insert and replacements, nanomaterials, nanosized ceramics, coating and cement are highly used in modern industries. The major parameters considered to optimize the biomaterials for tissue generation include Structural Components (physical, mechanical and chemical properties) and Biochemical Components (immobilized signals, diffusible signals, and living components). The bio-ceramics have good biocompatibility, osteoconductivity, osteoinductivity, biodegradability, resorbability, and hydrophilicity. So, there is a need of design, development, and deployment of the experimental set-up of ball milling operation to achieve homogeneous mixing of the ceramic matrix and reinforcement.

Keywords

Nanocomposites,Biomedical Applications, Dental Applications, Biocompatibility, Bioceramic Nanocomposites.

Introduction

Due to high applicability in the field of orthopedics, aerospace, automobiles, petroleum hydrotreatment, electronic insulators, fuel cells, and structures, there is no alternative of ceramics. To increase the mechanical properties, ceramics are fabricated with reinforcements, called ceramics matrix composites (CMCs).Nano-ceramic patches are nano-patches made primarily of pottery. Nano-ceramic patches are heat-resistant, non-metallic, and inorganic solids composed of both metallic and non-metallic chemicals from which a wide range of mixes may be created. Some of the functionalities are handed by nano-composites. Composites include dielectric, ferroelectric, piezoelectric, pyroelectric, ferromagnetic, magnetoresistive, superconductive, and electro-optical. The first nano-ceramic flyspeck was discovered in the early 1980s. They were created exercising a sol-gel fashion, which combines nanoparticles in a result and gel to produce the nanoparticle. Sintering was used after procedures. Because the material is so bitsy, there are nearly no faults. Larger scale accouterments are fragile due to blights. This construction may recapture its original shape after repeated smashing. Ceramic nanoparticles

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have been employed as a medicine delivery system in a variety of affections, including bacterial infections, glaucoma, and chemotherapy administration in experimental cancer treatment. Nano-tubes are ground into very tiny powders using the ball milling method. This method is mostly employed to mix ingredients and finely ground powders. This procedure is cost-effective, kind to the environment, and has found widespread use in business throughout the globe. Typically, it comprises a hollow cylindrical tank revolving around its axis that contains rubber, steel, stainless steel, ceramic, or glass balls. Reliability, simplicity of use, consistent outcomes owing to energy and speed control, and application in wet and dry circumstances on a variety of materials, including hydroxyapatite, are benefits of this sort of technology.Ceramic Matrix Composites (CMCs) executed a giant significance. Reinforcing Materials used for preparing ceramic matrix composites are carbon, alumina, silicon carbide, zirconium, Titanium, etc.

The excellent properties of Ceramics Matrix Composites (CMCs) have identified as many industrial applications to work, efficiently. There are several applications of ceramic matrix composite like aerospace and automotive applications, bone implantation in the orthopedic department, petroleum hydrotreating, potential adsorbent in chemical warfare, solar cells, instrument to sense humidity, fabrication in electronics appliances, fabricating electrolyte for solid oxide fuel cell, extreme speed cutting tool purpose, structures for gas turbine engines, insulating materials for electrical and thermal purposesIn the Ball milling process, the nanotubes are ground into incredibly tiny particles. Ball milling can damage the nanotubes even if it is simple to use and appropriate for powder polymers or monomers. Ball milling is frequently used for the creation of oxides, nanocomposite materials, and/or the improvement of structure/phase composition in addition to grinding powders. It is a mechanical process often used to create small particles from powders. By randomly impacting graphite (the precursor) with grinding media inside a revolving shell, this technique broke down the precursor, creating shear and compression force that helped overcome the weak Vander Waal's contact between the graphite layers and caused their splintering. Cost-effectiveness, dependability, simplicity of use, consistent results due to energy and speed control, and applicability in wet and dry circumstances on a variety of materials are all benefits of this technology. Moreover, there are certain drawbacks, such as the potential for contamination, the development of nanomaterials with irregular shapes, noise, and lengthy grinding [1-2].

Literature Review

Li et al studied the enhancement of the automated settings of excellent ceramics manufactured by layer-based manufacturing is essentially related to the broad function. In this study, a range of yttria-stabilized zirconia (YSZ) materials with zirconia toughened alumina (ZTA) capacity were satisfied and manufactured through optical fabrication techniques planted on the self-holding capacity of the viscoelasticity fix & function of adaptable contact base method. Linking microstructural investigation and automatic appraisal by three-point curving & impression analysis, the effect of YSZ on the SL procedure & consecutive automatic characteristics was explained. Hence the outcome shows that the advanced corresponding coil power (477.54 MPa) & fracture grit (6.56 MPa m1/2) were taken by ZTA ceramic with a YSZ content of 20 wt.% [3].**Wachowski et al** studied Ti /Al_2O_3 ceramic metal compound gained with the help of slip-casting process fragments overall 50 volumes of the solid-state along with 10 volumes of the

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metal state were checked the rheological prospects which concluded a thermogravimetric study achieved the characteristics of gained compound resolved the step formation by applying SEM/EDS micro-structural study the approach of XRD of the size of titanium particles equivalent to 20.6± 101 mm which coincides with 275 of original capacity [4].

Fatemeh et al observed that the balanced slurries were the distributed variety of popular Al_2O_3 and Y_2O_3 granules, ammonium poly meta-acrylate (Dolapix CE-64) as the Dissipate, and tetraethyl orthosilicate (TEOS) as the heating aid were made by ball milling method. The outcome of the time of milling on the fabrication of clear polycrystalline yttrium aluminum garnet (YAG) ceramics were inspected by slip casting and vacuum sintering. The outcomes show that the perfect milling time for the deagglomeration of the powder blend was 16 hours and the slurry adapted at this time shows a near- Newtonian action due to the superior deagglomeration and low viscosity. radiography arrangements also produced all patterns in pure YAG state. The outcome also exposed that the patterns prepared by 16 hours of ball milling time break presented more relative green & finishing density and maximal change at 1064 nm (≈ 77%) [5].

Bechteler et al delved Carbon nanotube (CNT) corroborated alumina nanocomposite They discovered that grain size has a considerable impact on the percolation threshold of electrical conductivity, performing in anisotropic characteristics. They also discovered that when CNT attention increases, thermal conductivity falls vastly. They determined that the electrical conductivity of CNT/ alumina mixes is dependent on the main greasepaint flyspeck size and that an increase in CNT content increases porosity, which imposes anisotropic electrical conductivity. They concluded to the conclusion that characterizing the independent impact of Carbon nanotube content and porosity on thermal conductivity revealed that adding Carbon nanotube content at constant porosity, as well as adding porosity at constant Carbon nanotube, results in a considerable drop in thermal conductivity [6]. **Idrees et al** fitted a ball milling process, delved Silicon boron carbon nitride (SiBCN) ceramic mixes filled with nitrogen sulfur binary-doped graphene (NSG) distance (SiBCN/NSGs) were cooked and manufactured. They discovered that NSGs are foreign excrescencies that increase electrode performance and have a reversible capacity of 785 mAh. They conclude that the goods of nitrogen sulfur binary-doped graphene (NSG) distance active anode material were attained through pyrolysis at 600 °C, 800 °C, and 1000 °C and that these unique silicon-grounded carbon accouterments have great eventuality to be used for other operations similar to electromagnetic hindrance [7].

Song et al delved UV- curable and high-density ZrO_2 ceramic nanocomposite resins. They employed APTMS-carpeted ZrO_2 ceramic patches with di and tri-functional acrylate monomers with non-reactive diluents, grounded on a percolating network with 50 ceramic patches and a high density, to increase their dissipation stability and print-curing cap behavior abilities. At 1450 °C, the green bodies of 3D-published objects with varying cross-linking consistency were sintered. Grounded on the results of density and UV curing rheological and print-curing behaviors, they conclude that IPA attention was stylish at 20 monomers [8].

Asl et al explored the mongrel ZrB_2 a grounded compound with 10 nano-sized carbon dark and 20 SiC and manufactured by vacuum hot pressing for 60 twinkles at 1850 °C under 20 MPa. The sintered ceramic's structure and sintering ability were delved into using X-ray grease paint diffraction, surveying electron microscopy, and X-ray spectroscopy. They find that no conspicuous in situ-generated new phases were observed at the graphite ZrB_2 and SiC grain

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contact. Even though the densification process was chemically inert, some of the unformed carbon black patches changed into liquid graphite nano-flakes during hot pressing [9].

Eatemadi & Balakl analyzed the influence of sintering settings on the fracture durability and densification of spark tube sintering nanocomposites. They sintered ZrB_2 30% vol SiC nanocomposites at 1600-1800 °C for 8-12 min. They delved into the microstructural differences using Scanning Electron Microscopy (SEM). They discovered that raising the sintering temperature redounded in a minor increase in SiC grain size but no sensible variation in ZrB_2, and that adding the sintering duration redounded in an increase in both ZrB_2 and SiC grain size. They concluded that analysis of SEM images and path propagation revealed that crack divagation and branching are asked toughening processes in ZrB_2- SiC nanocomposites [10].

Lu et al delved free-standing and flexible polymer-ceramic nanocomposite flicks and created them using a spin-coating procedure using poly (vinylidene fluoride-co-hexafluoropropylene) as the matrix and $BaTiO_3$ (BTO) nanoparticles as the padding. They discovered that adding the BTO attention reduces crystallinity and demitasse size in the P (VDF- HFP) matrix. They find that dielectric responses produced in compound flicks are affected by temperature and frequency, and the goods of the ceramic padding on the four dielectric processes of the polymer matrix were delved. They find that when the BTO attention increases, so do the crystallinity and size of the P(VDFHFP) matrix chargers. Because of the high r and low tan of BTO padding, the r increases and the tan drops with adding BTO attention at room temperature [11].

Wagih et al carpeted Ag nanoparticles with mongrel Cu- Al_2O_3 nanocomposites were delved, and new mixes with bettered mechanical, electrical, and thermal parcels were developed. Compressive strength, hardness, thermal, and electrical parcels were also delved. They discovered that adding GNPs improves compressive strength and hardness by 88.1 and 55.2, independently [12]. **Ghayour et al** used different types of scenarios that increase the BPR such as weight loss of powder, change of diameter, and the number of balls and their effects on the milling efficiency. They noticed that results show the loss of powder weight can greatly enhance the performance of milling. When the quantity of balls is increased at a high BPR ratio, it influences the milling performance which is negative. They obtained results, if the vial-to-plate spinning rate is 1.2, however by an increase in diameter the mill had a good performance, and this ratio is changed to 1.4 [13].

Jayaramudu et al used nanoparticles of silver with a size of crystallite range between 10 and 12 nm, synthesized poly (ethylene glycol) which is of different molecular weights as agents [14].

Song et al prepared the composite of CNTs/Cu through the electroless plating and planetary ball milling process. They noticed that the results show that copper particles are deposited homogeneously on carbon nano-tubes surface. It was discovered that when comparing composite with electroless plating to composite without, the tensile strength of the latter improves noticeably, up to 207 MPa. The cold drawing was successful in producing composite materials with greater tensile strength. The mechanical characteristics of the composites have been increased, according to the results. The tensile strength and yield strength are respectively up to 311 MPa and 185 MPa [15]. **Zhang et al** show graphene as the ideal reinforcement because of its favorable mechanical and physical characteristics. They employed milling balls with a tiny diameter and strengthened graphene nanoplates to minimize the impact energy during the ball milling process. Ball milling was used to successfully create composite materials made of the Al-

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5083 alloy. By using X-ray diffraction, the structures of the micro-level ball-milled powders and GNP/Al-5083 composites were identified. The outcomes demonstrated that the GNP persisted after ball milling. While some GNP may have interacted with Al to generate Al_4C_3 during the merging process, the Al_4C_3 phase was discovered in bulk GNP/Al-5083 composites [16].

Oqail et al used copper nanocomposites assisted by 5 and 10 wt.% of ZrO_2 compound particles. Nanocomposite powder which is produced was examined by X-ray diffraction and transmission electron microscopy (TEM). The produced powders were then subjected to cold compaction at a pressure of 700 MPa and sintered for two hours at 950 °C in a hydrogen environment. This demonstrates that increasing the milling time increases the produced nanocomposites' microhardness. After 20 hours of milling, Cu-10%ZrO_2 has 3.76 times the microhardness of pure Cu [17]. **Wirunchit et al** noticed that the size and morphology of ZnO nanoparticles varied depending on the calcination temperature, which ranged from 400-900 C. It was investigated that high-purity ZnO is obtained around 800 °C [18].

Problem Formulation

On the basis of the literature review, various types of ceramics and ceramic matrix composites are highly applicable in various industries such as orthopedics, aerospace, automobiles, petroleum hydrotreatment, electronic insulators, fuel cells, and structures. There is a wide range of powder ceramic materials has been investigated such as alumina, nickel oxide, magnesium oxide, yttria-stabilized zirconia, silicon nitride, silicon carbide, bio-glass, hydroxyapatite, calcium phosphate, tricalcium phosphates, titanium oxides, yttrium silicate, phosphorus pentoxide, calcium oxide, barium titanate, ferric oxide, polyciliate, lead zirconate titanate, polycarbazole, divinyl benzene, LSCF ($La_{0.6}.Sr_{0.4}.Co_{0.2}.Fe_{0.8}.O_3$), CGO ($Ce_{0.9}.Gd_{0.1}.O_{1.95}$), etc. Many researchers introduced various binders and additives such as water, silica sol, camphene, naphthalene, oligomeric polyester, polyethylene glycol, ammonium polymethacrylate, glycerol, 4-hydroxy butyl acrylate, polyvinyl butyral, tert-butyl acrylate, tetraethyl-orthosilicate, nitric acid, isopropyl alcohol, gelatin, etc [19-25]. CMCs have been mixed under the action of ball milling operations. Generally, the ball milling processes have been implemented by either rotation or reciprocating of the mixing drum. In a rotating type mixing drum, the spherical steel or ceramic balls rotate inside the cylinder under the action of centrifugal forces and generate the problem of sticking the materials on the inner circular wall sections. The problem with the reciprocating mixing drum is that the spherical balls are sedimented in the solution under the action of gravity force. In both cases, the non-uniform and heterogeneous phases of slurry have been observed. The main objective of this research is to eliminate these critical issues through a mechanism, named as oscillating drum ball milling process.

Design and Fabrication of Experimental Set up

Based on the investigations as per literature reviews, the experimental set-up of ball milling equipment has been designed and fabricated.

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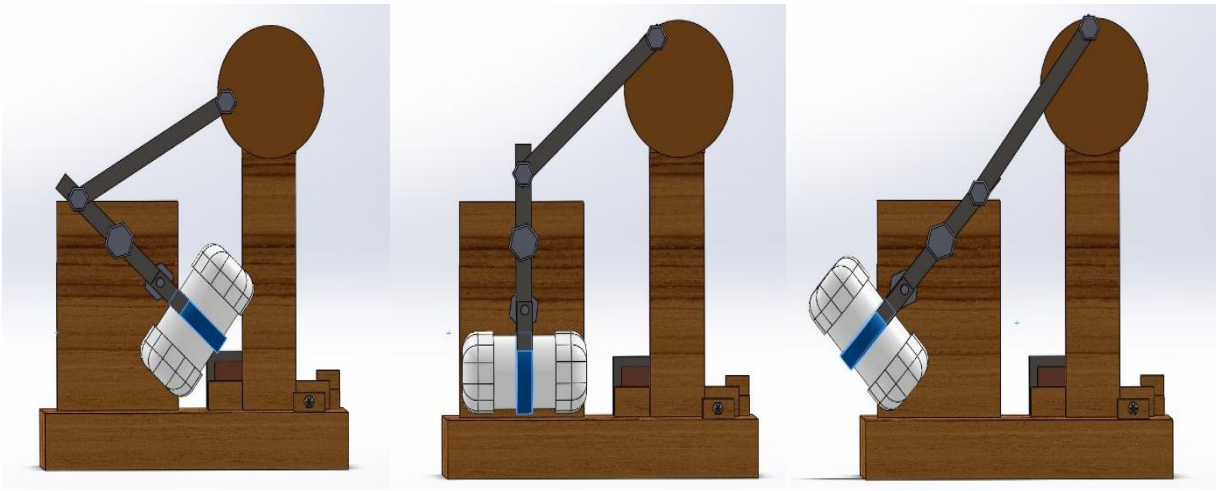


Figure - 1 Design and Assembly of Oscillating Ball Milling Set up in different positions.

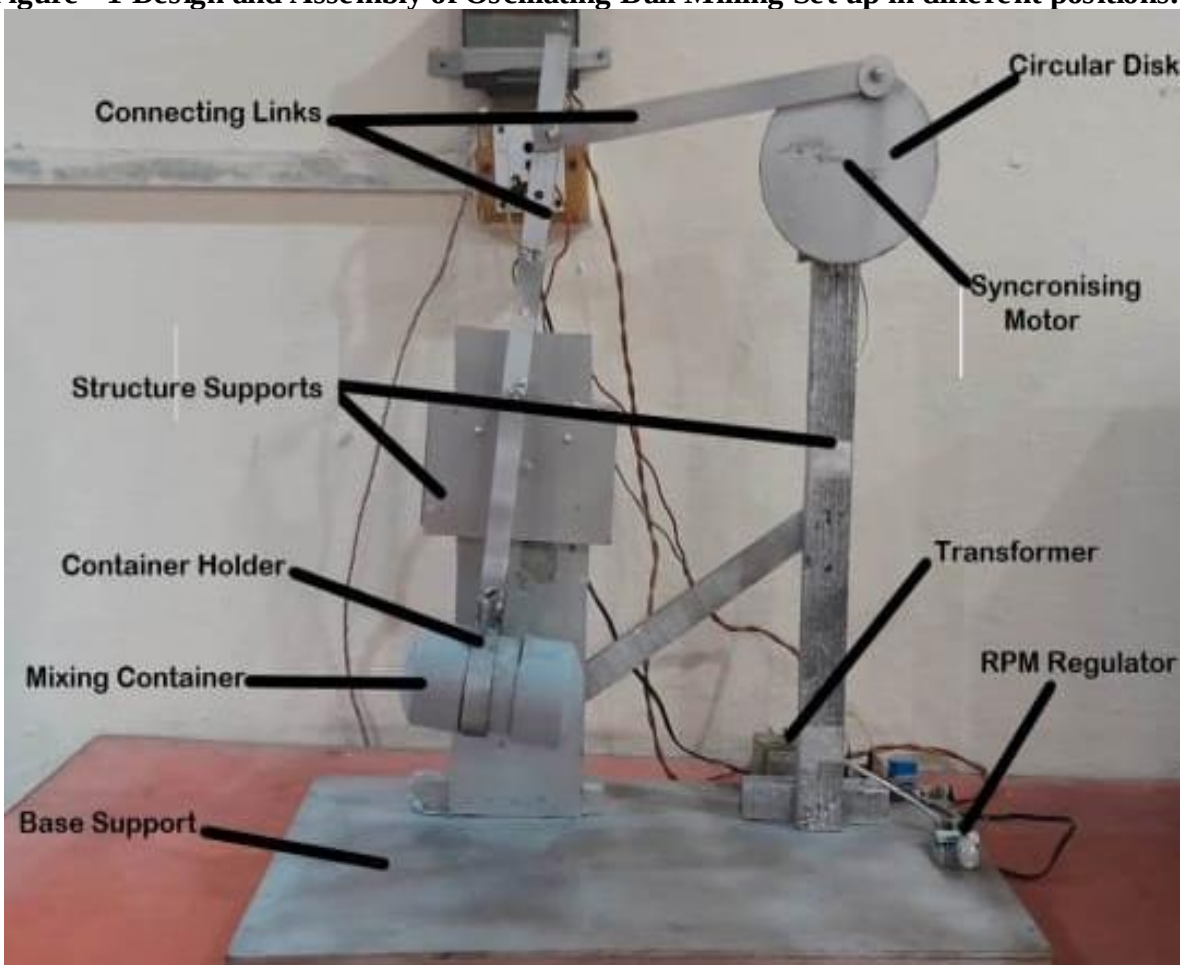


Figure-2 Fabrication of Oscillating Ball Milling Set up

The design and fabrication of the oscillating ball milling setup is based on the mechanism of the conversion of rotatingmotion into oscillating motion. It has three different speed variations of the

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circular disk as 500 rpms, 900 rpms, and 1300 rpms with the help of a speed regulator as shown in figure 1 and figure 2.

This setup works on the concept of kinetics of motion conversion. As the synchronized motor has been rotated by the controlled commanding through the rpm regulator and transformation, this rotation motion of the circular disc is transferred to the connected rod. The connected rod converts rotation motion into oscillating motion. On the other end of the oscillating arm, the linkage of the drum is attached. So, the ceramics in powder forms generate more uniform and homogeneous mixing.

Conclusions

This review work represented the industrial applications of different types of ceramics as well as ceramics matrix composites, their mixing process, and manufacturing processes. It demonstrated the present and future aspects of ball milling operations. The improvement in the various mechanical as well as rheological properties such as density, viscosity, homogeneity, flowability, etc., may be a remarkable achievement in the mixing process of solution.

Future Scope

The optimization of orthopedic and dental implantation is an important area of research that has significant potential for future advancements. Some of the future scopes of this research can include:

- **Development of new materials:** The current orthopedic and dental implant materials have limitations in terms of mechanical strength, biocompatibility, and durability. The optimization ofimplantation techniques can lead to the development of new materials with enhanced properties and functionality, such as biodegradability, osteoinduction, and antibacterial activity.
- **Personalized implants:** The optimization of implantation techniques can also lead to the development of personalized implants that are tailored to the individual patient's anatomy and physiological needs. This can improve the implant's fit, stability, and longevity, leading to better clinical outcomes and patient satisfaction.
- **Implant monitoring:** The optimization of implantation techniques can also lead to the development of new monitoring techniques that can detect implant failure or complications early on. This can improve the clinical management of patients and reduce the need for revision surgery.
- **Optimization of surgical techniques:** The optimization of implantation techniques can also lead to the development of new surgical techniques that can improve the accuracy, efficiency, and safety of the surgical procedure. This can reduce surgical time, minimize the risk of complications,and improve the patient's overall experience.

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CERAMIC MATRIX NANOCOMPOSITE IN BIOMEDICAL AND DENTAL APPLICATIONS -A REVIEW

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Abstract

Nanocomposites are playing an important role in the areas of medicine, biology and electronics. In biomedical and dental insert and replacements, nanomaterials, nanosized ceramics, coating and cement are highly used in modern industries. The major parameters considered to optimize the biomaterials for tissue generation include Structural Components (physical, mechanical and chemical properties) and Biochemical Components (immobilized signals, diffusible signals, and living components). The bio-ceramics have good biocompatibility, osteoconductivity, osteoinductivity, biodegradability, resorbability, and hydrophilicity. So, there is a need of design, development, and deployment of the experimental set-up of ball milling operation to achieve homogeneous mixing of the ceramic matrix and reinforcement.

Keywords

Nanocomposites, Biomedical Applications, Dental Applications, Biocompatibility, Bioceramic Nanocomposites.

Introduction

Due to high applicability in the field of orthopedics, aerospace, automobiles, petroleum hydrotreatment, electronic insulators, fuel cells, and structures, there is no alternative of ceramics. To increase the mechanical properties, ceramics are fabricated with reinforcements, called ceramics matrix composites (CMCs).Nano-ceramic patches are nano-patches made primarily of pottery. Nano-ceramic patches are heat-resistant, non-metallic, and inorganic solids composed of both metallic and non-metallic chemicals from which a wide range of mixes may be created. Some of the functionalities are handed by nano-composites. Composites include dielectric, ferroelectric, piezoelectric, pyroelectric, ferromagnetic, magnetoresistive, superconductive, and electro-optical. The first nano-ceramic flyspeck was discovered in the early 1980s. They were created exercising a sol-gel fashion, which combines nanoparticles in a result and gel to produce the nanoparticle. Sintering was used after procedures. Because the material is

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so bitsy, there are nearly no faults. Larger scale accouterments are fragile due to blights. This construction may recapture its original shape after repeated smashing. Ceramic nanoparticles have been employed as a medicine delivery system in a variety of affections, including bacterial infections, glaucoma, and chemotherapy administration in experimental cancer treatment. Nano-tubes are ground into very tiny powders using the ball milling method. This method is mostly employed to mix ingredients and finely ground powders. This procedure is cost-effective, kind to the environment, and has found widespread use in business throughout the globe. Typically, it comprises a hollow cylindrical tank revolving around its axis that contains rubber, steel, stainless steel, ceramic, or glass balls. Reliability, simplicity of use, consistent outcomes owing to energy and speed control, and application in wet and dry circumstances on a variety of materials, including hydroxyapatite, are benefits of this sort of technology.Ceramic Matrix Composites (CMCs) executed a giant significance. Reinforcing Materials used for preparing ceramic matrix composites are carbon, alumina, silicon carbide, zirconium, Titanium, etc.

The excellent properties of Ceramics Matrix Composites (CMCs) have identified as many industrial applications to work, efficiently. There are several applications of ceramic matrix composite like aerospace and automotive applications, bone implantation in the orthopedic department, petroleum hydrotreating, potential adsorbent in chemical warfare, solar cells, instrument to sense humidity, fabrication in electronics appliances, fabricating electrolyte for solid oxide fuel cell, extreme speed cutting tool purpose, structures for gas turbine engines, insulating materials for electrical and thermal purposesIn the Ball milling process, the nanotubes are ground into incredibly tiny particles. Ball milling can damage the nanotubes even if it is simple to use and appropriate for powder polymers or monomers. Ball milling is frequently used for the creation of oxides, nanocomposite materials, and/or the improvement of structure/phase composition in addition to grinding powders. It is a mechanical process often used to create small particles from powders. By randomly impacting graphite (the precursor) with grinding media inside a revolving shell, this technique broke down the precursor, creating shear and compression force that helped overcome the weak Vander Waal's contact between the graphite layers and caused their splintering. Cost-effectiveness, dependability, simplicity of use, consistent results due to energy and speed control, and applicability in wet and dry circumstances on a variety of materials are all benefits of this technology. Moreover, there are certain drawbacks, such as the potential for contamination, the development of nanomaterials with irregular shapes, noise, and lengthy grinding [1-2].

Literature Review

Li et al studied the enhancement of the automated settings of excellent ceramics manufactured by layer-based manufacturing is essentially related to the broad function. In this study, a range of yttria-stabilized zirconia (YSZ) materials with zirconia toughened alumina (ZTA) capacity were satisfied and manufactured through optical fabrication techniques planted on the self-holding capacity of the viscoelasticity fix & function of adaptable contact base method. Linking microstructural investigation and automatic appraisal by three-point curving & impression analysis, the effect of YSZ on the SL procedure & consecutive automatic characteristics was explained. Hence the outcome shows that the advanced corresponding coil power (477.54 MPa) & fracture grit (6.56 MPa m1/2) were taken by ZTA ceramic with a YSZ content of 20 wt.%

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[3].**Wachowski et al** studied Ti /Al_2O_3 ceramic metal compound gained with the help of slip-casting process fragments overall 50 volumes of the solid-state along with 10 volumes of the metal state were checked the rheological prospects which concluded a thermogravimetric study achieved the characteristics of gained compound resolved the step formation by applying SEM/EDS micro-structural study the approach of XRD of the size of titanium particles equivalent to 20.6± 101 mm which coincides with 275 of original capacity [4].

Fatemeh et al observed that the balanced slurries were the distributed variety of popular Al_2O_3 and Y_2O_3 granules, ammonium poly meta-acrylate (Dolapix CE-64) as the Dissipate, and tetraethyl orthosilicate (TEOS) as the heating aid were made by ball milling method. The outcome of the time of milling on the fabrication of clear polycrystalline yttrium aluminum garnet (YAG) ceramics were inspected by slip casting and vacuum sintering. The outcomes show that the perfect milling time for the deagglomeration of the powder blend was 16 hours and the slurry adapted at this time shows a near- Newtonian action due to the superior deagglomeration and low viscosity. radiography arrangements also produced all patterns in pure YAG state. The outcome also exposed that the patterns prepared by 16 hours of ball milling time break presented more relative green & finishing density and maximal change at 1064 nm (≈ 77%) [5].

Bechteler et al delved Carbon nanotube (CNT) corroborated alumina nanocomposite They discovered that grain size has a considerable impact on the percolation threshold of electrical conductivity, performing in anisotropic characteristics. They also discovered that when CNT attention increases, thermal conductivity falls vastly. They determined that the electrical conductivity of CNT/ alumina mixes is dependent on the main greasepaint flyspeck size and that an increase in CNT content increases porosity, which imposes anisotropic electrical conductivity. They concluded to the conclusion that characterizing the independent impact of Carbon nanotube content and porosity on thermal conductivity revealed that adding Carbon nanotube content at constant porosity, as well as adding porosity at constant Carbon nanotube, results in a considerable drop in thermal conductivity [6]. **Idrees et al** fitted a ball milling process, delved Silicon boron carbon nitride (SiBCN) ceramic mixes filled with nitrogen sulfur binary-doped graphene (NSG) distance (SiBCN/NSGs) were cooked and manufactured. They discovered that NSGs are foreign excrescencies that increase electrode performance and have a reversible capacity of 785 mAh. They conclude that the goods of nitrogen sulfur binary-doped graphene (NSG) distance active anode material were attained through pyrolysis at 600 °C, 800 °C, and 1000 °C and that these unique silicon-grounded carbon accouterments have great eventuality to be used for other operations similar to electromagnetic hindrance [7].

Song et al delved UV- curable and high-density ZrO_2 ceramic nanocomposite resins. They employed APTMS-carpeted ZrO_2 ceramic patches with di and tri-functional acrylate monomers with non-reactive diluents, grounded on a percolating network with 50 ceramic patches and a high density, to increase their dissipation stability and print-curing cap behavior abilities. At 1450 °C, the green bodies of 3D-published objects with varying cross-linking consistency were sintered. Grounded on the results of density and UV curing rheological and print-curing behaviors, they conclude that IPA attention was stylish at 20 monomers [8].

Asl et al explored the mongrel ZrB_2 a grounded compound with 10 nano-sized carbon dark and 20 SiC and manufactured by vacuum hot pressing for 60 twinkles at 1850 °C under 20 MPa. The sintered ceramic's structure and sintering ability were delved into using X-ray grease paint

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diffraction, surveying electron microscopy, and X-ray spectroscopy. They find that no conspicuous in situ-generated new phases were observed at the graphite ZrB_2 and SiC grain contact. Even though the densification process was chemically inert, some of the unformed carbon black patches changed into liquid graphite nano-flakes during hot pressing [9]. **Eatemadi & Balakl** analyzed the influence of sintering settings on the fracture durability and densification of spark tube sintering nanocomposites. They sintered ZrB_2 30% vol SiC nanocomposites at 1600-1800 °C for 8-12 min. They delved into the microstructural differences using Scanning Electron Microscopy (SEM). They discovered that raising the sintering temperature redounded in a minor increase in SiC grain size but no sensible variation in ZrB_2, and that adding the sintering duration redounded in an increase in both ZrB_2 and SiC grain size. They concluded that analysis of SEM images and path propagation revealed that crack divagation and branching are asked toughening processes in ZrB_2- SiC nanocomposites [10].

Lu et al delved free-standing and flexible polymer-ceramic nanocomposite flicks and created them using a spin-coating procedure using poly (vinylidene fluoride-co-hexafluoropropylene) as the matrix and $BaTiO_3$ (BTO) nanoparticles as the padding. They discovered that adding the BTO attention reduces crystallinity and demitasse size in the P (VDF- HFP) matrix. They find that dielectric responses produced in compound flicks are affected by temperature and frequency, and the goods of the ceramic padding on the four dielectric processes of the polymer matrix were delved. They find that when the BTO attention increases, so do the crystallinity and size of the P(VDFHFP) matrix chargers. Because of the high r and low tan of BTO padding, the r increases and the tan drops with adding BTO attention at room temperature [11].

Wagih et al carpeted Ag nanoparticles with mongrel Cu- Al_2O_3 nanocomposites were delved, and new mixes with bettered mechanical, electrical, and thermal parcels were developed. Compressive strength, hardness, thermal, and electrical parcels were also delved. They discovered that adding GNPs improves compressive strength and hardness by 88.1 and 55.2, independently [12]. **Ghayour et al** used different types of scenarios that increase the BPR such as weight loss of powder, change of diameter, and the number of balls and their effects on the milling efficiency. They noticed that results show the loss of powder weight can greatly enhance the performance of milling. When the quantity of balls is increased at a high BPR ratio, it influences the milling performance which is negative. They obtained results, if the vial-to-plate spinning rate is 1.2, however by an increase in diameter the mill had a good performance, and this ratio is changed to 1.4 [13].

Jayaramudu et al used nanoparticles of silver with a size of crystallite range between 10 and 12 nm, synthesized poly (ethylene glycol) which is of different molecular weights as agents [14]. **Song et al** prepared the composite of CNTs/Cu through the electroless plating and planetary ball milling process. They noticed that the results show that copper particles are deposited homogeneously on carbon nano-tubes surface. It was discovered that when comparing composite with electroless plating to composite without, the tensile strength of the latter improves noticeably, up to 207 MPa. The cold drawing was successful in producing composite materials with greater tensile strength. The mechanical characteristics of the composites have been increased, according to the results. The tensile strength and yield strength are respectively up to 311 MPa and 185 MPa [15]. **Zhang et al** show graphene as the ideal reinforcement because of its favorable mechanical and physical characteristics. They employed milling balls with a tiny

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diameter and strengthened graphene nanoplates to minimize the impact energy during the ball milling process. Ball milling was used to successfully create composite materials made of the Al-5083 alloy. By using X-ray diffraction, the structures of the micro-level ball-milled powders and GNP/Al-5083 composites were identified. The outcomes demonstrated that the GNP persisted after ball milling. While some GNP may have interacted with Al to generate Al_4C_3 during the merging process, the Al_4C_3 phase was discovered in bulk GNP/Al-5083 composites [16].

Oqail et al used copper nanocomposites assisted by 5 and 10 wt.% of ZrO_2 compound particles. Nanocomposite powder which is produced was examined by X-ray diffraction and transmission electron microscopy (TEM). The produced powders were then subjected to cold compaction at a pressure of 700 MPa and sintered for two hours at 950 °C in a hydrogen environment. This demonstrates that increasing the milling time increases the produced nanocomposites' microhardness. After 20 hours of milling, Cu-10%ZrO_2 has 3.76 times the microhardness of pure Cu [17]. **Wirunchit et al** noticed that the size and morphology of ZnO nanoparticles varied depending on the calcination temperature, which ranged from 400-900 C. It was investigated that high-purity ZnO is obtained around 800 °C [18].

Problem Formulation

On the basis of the literature review, various types of ceramics and ceramic matrix composites are highly applicable in various industries such as orthopedics, aerospace, automobiles, petroleum hydrotreatment, electronic insulators, fuel cells, and structures. There is a wide range of powder ceramic materials has been investigated such as alumina, nickel oxide, magnesium oxide, yttria-stabilized zirconia, silicon nitride, silicon carbide, bio-glass, hydroxyapatite, calcium phosphate, tricalcium phosphates, titanium oxides, yttrium silicate, phosphorus pentoxide, calcium oxide, barium titanate, ferric oxide, polyciliate, lead zirconate titanate, polycarbazole, divinyl benzene, LSCF ($La_{0.6}.Sr_{0.4}.Co_{0.2}.Fe_{0.8}.O_3$), CGO ($Ce_{0.9}.Gd_{0.1}.O_{1.95}$), etc. Many researchers introduced various binders and additives such as water, silica sol, camphene, naphthalene, oligomeric polyester, polyethylene glycol, ammonium polymethacrylate, glycerol, 4-hydroxy butyl acrylate, polyvinyl butyral, tert-butyl acrylate, tetraethyl-orthosilicate, nitric acid, isopropyl alcohol, gelatin, etc [19-25]. CMCs have been mixed under the action of ball milling operations. Generally, the ball milling processes have been implemented by either rotation or reciprocating of the mixing drum. In a rotating type mixing drum, the spherical steel or ceramic balls rotate inside the cylinder under the action of centrifugal forces and generate the problem of sticking the materials on the inner circular wall sections. The problem with the reciprocating mixing drum is that the spherical balls are sedimented in the solution under the action of gravity force. In both cases, the non-uniform and heterogeneous phases of slurry have been observed. The main objective of this research is to eliminate these critical issues through a mechanism, named as oscillating drum ball milling process.

Design and Fabrication of Experimental Set up

Based on the investigations as per literature reviews, the experimental set-up of ball milling equipment has been designed and fabricated.

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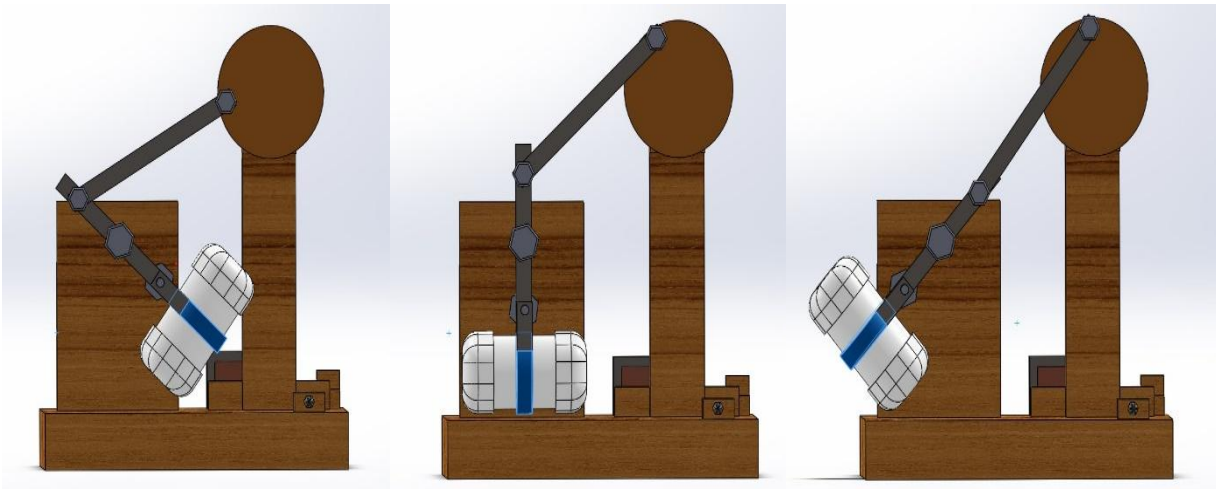


Figure - 1 Design and Assembly of Oscillating Ball Milling Set up in different positions.

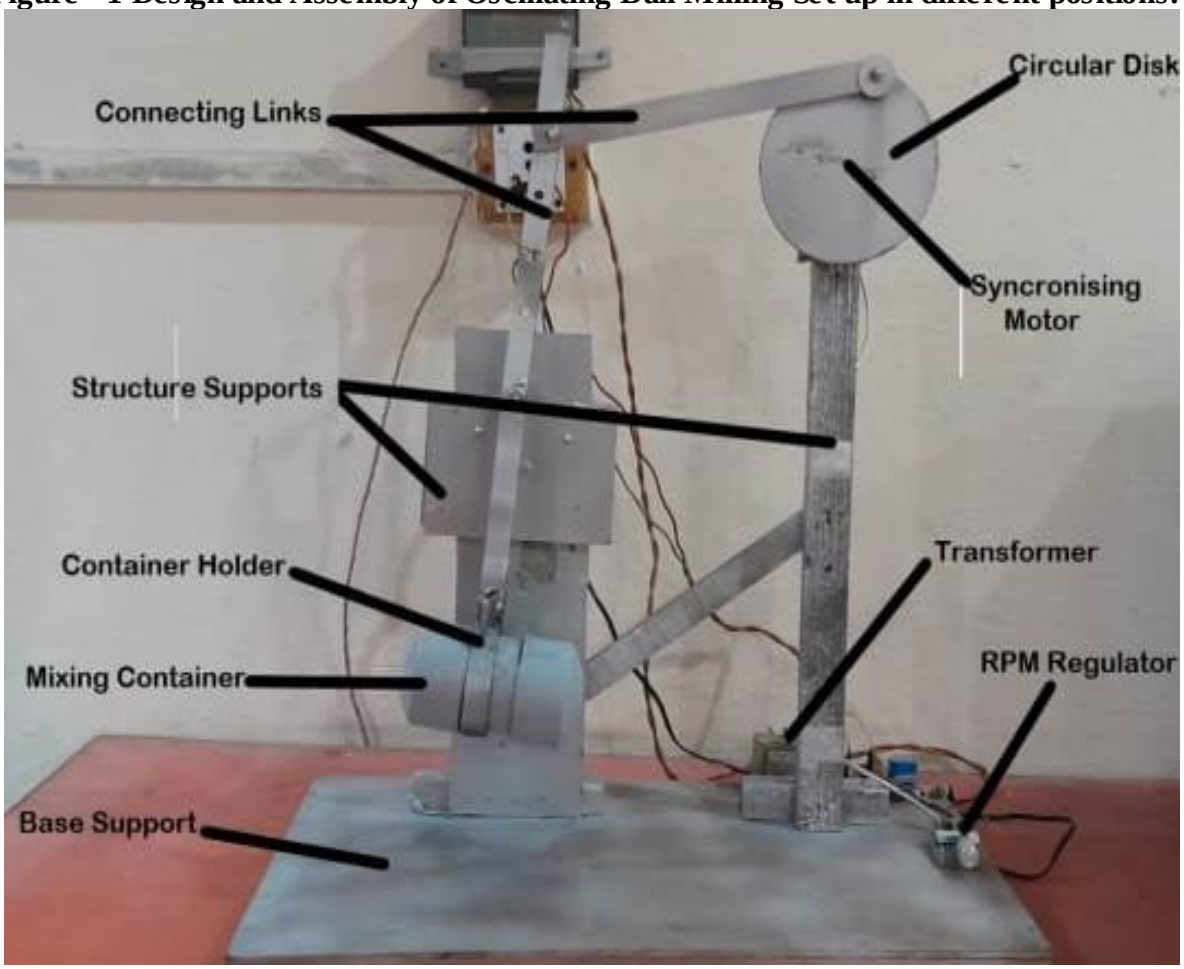


Figure-2 Fabrication of Oscillating Ball Milling Set up

The design and fabrication of the oscillating ball milling setup is based on the mechanism of the conversion of rotatingmotion into oscillating motion. It has three different speed variations of the

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circular disk as 500 rpms, 900 rpms, and 1300 rpms with the help of a speed regulator as shown in figure 1 and figure 2.

This setup works on the concept of kinetics of motion conversion. As the synchronized motor has been rotated by the controlled commanding through the rpm regulator and transformation, this rotation motion of the circular disc is transferred to the connected rod. The connected rod converts rotation motion into oscillating motion. On the other end of the oscillating arm, the linkage of the drum is attached. So, the ceramics in powder forms generate more uniform and homogeneous mixing.

Conclusions

This review work represented the industrial applications of different types of ceramics as well as ceramics matrix composites, their mixing process, and manufacturing processes. It demonstrated the present and future aspects of ball milling operations. The improvement in the various mechanical as well as rheological properties such as density, viscosity, homogeneity, flowability, etc., may be a remarkable achievement in the mixing process of solution.

Future Scope

The optimization of orthopedic and dental implantation is an important area of research that has significant potential for future advancements. Some of the future scopes of this research can include:

- **Development of new materials:** The current orthopedic and dental implant materials have limitations in terms of mechanical strength, biocompatibility, and durability. The optimization ofimplantation techniques can lead to the development of new materials with enhanced properties and functionality, such as biodegradability, osteoinduction, and antibacterial activity.
- **Personalized implants:** The optimization of implantation techniques can also lead to the development of personalized implants that are tailored to the individual patient's anatomy and physiological needs. This can improve the implant's fit, stability, and longevity, leading to better clinical outcomes and patient satisfaction.
- **Implant monitoring:** The optimization of implantation techniques can also lead to the development of new monitoring techniques that can detect implant failure or complications early on. This can improve the clinical management of patients and reduce the need for revision surgery.
- **Optimization of surgical techniques:** The optimization of implantation techniques can also lead to the development of new surgical techniques that can improve the accuracy, efficiency, and safety of the surgical procedure. This can reduce surgical time, minimize the risk of complications,and improve the patient's overall experience.

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Improved Piezoelectric Properties in PVDF based Nanocomposites using different nanofillers for Energy Harvesting Applications

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Abstract

With the current massive use of fossil fuels, there is a large demand for lightweight, high-performing power supply systems to maintain a pollution-free environment. Due to their superior mechanical qualities, piezoelectric nanogenerators (NGs) become great choices for long-lasting, wireless energy electrical gadgets. Excellent flexibility and strength, ease of processing, and best suited for flexible piezoelectric polymer materials are the attributes of PVDF and its copolymers. Researchers have worked very hard to advance PVDF-based NGs to increase output performance. A critical review is offered to improve the β phase and piezoelectric response in PVDF based composites, since the β phase of PVDF has gained increased attention in piezoelectric applications. The effects of different nanofillers are investigated for use in energy harvesting (EH). Additionally, several current issues and potential uses for flexible PVDF-based NGs are covered.

Keywords: polyvinylidene fluoride, Composites films, Piezoelectricity

Introduction

Researchers are paying more attention to self-sustaining energy due to the massive usage of fossil fuels. Devices that are compact and inexpensive are in demand, but charging them can be challenging. As a result, there is a need for tiny, self-powered devices, which are only achievable with the aid of piezoelectric materials [1-4]. The piezoelectric effect is the term as a phenomenon where electrical charges split in reaction to the mechanical force [5]. However, they are linked with difficult manufacturing techniques, have a high density, are brittle and inflexible, have a lower voltage coefficient, and are hazardous in nature [6-8]. Because polymers have a greater dielectric breakdown characteristic, they can withstand larger driving forces. The maximal functional field strength of polymers is greater than that of ceramics. Piezoelectric polymers are appropriate for technological applications and functional device topologies because of their intriguing properties [9, 10]. A significant quantity of energy is lost in the environment as heat, noise, and other types of waste. Optimal utilization of ambient energy may be achieved through the selection of piezoelectric devices. This review study examines polyvinylidene fluoride (PVDF) and its copolymers that are filled with both organic and inorganic fillers [11]. About 50% of PVDF is made up of lamellar crystals, which can be embedded in an amorphous matrix and range in thickness and length to 100nm [12]. With a piezoelectric constant that is around five times greater than other piezoelectric polymers, PVDF is an appropriate piezoelectric polymer [13]. With its high piezoelectric constant, lightweight, ease of production, and long-term stability, PVDF is

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an appealing organic polymer. PVDF is an appropriate polymer for foldable electronic devices due to its high mechanical flexibility and thermal stability. The five uniquepolymorphs of the semi-crystalline PVDF are based on varied chain conformations. As seen in Fig. 1, there are five distinct phases of PVDF: α, β, γ, δ, along with ε. Because of its anti-parallel dipole packing, TGTG′ (trans-gauche–trans gauche) is a non-polar α phase that produces a non-electroactive phase in the unit cell. All the individual molecules' dipoles are placed parallel to each other in the TTTT structure of β and the TTTGTTTG structure of γ. Because all the dipoles are arranged in parallel to one another, β and γ cause a non-zero dipole moment and induce polarity. Compared to piezoelectric polymers, monolithic piezoceramic materials such as lithium niobate, lead zirconate titanate (PZT), barium titanate, and lead titanate are inherently brittle and rigid. Materials made of polymers are more suited to create various flexible gadgets. Lightweight, flexible, soft, extremely resistant to corrosion and UV radiation, poor heat conductor, and having limited permeability to many gases and liquids are all characteristics of the piezoelectric polymer PVDF. [14-16]. The characteristics of the five phases of PVDF vary based on the chain orientation. Because a gauche bond exits every fourth repetition unit, the γ phase's piezoelectric action is shown to be smaller than the β phase. Out of the five phases, the β phase of PVDF exhibits the finest pyroelectric, ferroelectric, and piezoelectric qualities. Because of its all-trans planar zigzag conformation and well-oriented polarized structure, the β phase exhibits excellent ferroelectric characteristics.

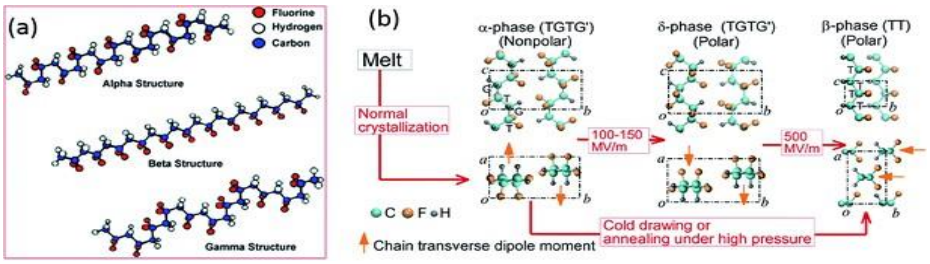


Fig.1 Different phases of PVDF polymer Ref.17

Piezoelectricity in the PVDF may be increased using a variety of techniques. Rolling, stretching, and probing are examples of physical techniques that can increase piezoelectricity. By adding different nucleating agents into the matrix, the dielectric and piezoelectric properties of the polymers may be changed without sacrificing their mechanical strength or flexibility. High energy-density capacitors are entering a new age thanks to polymer-based composite materials. Numerous studies have demonstrated how the nucleating agents' and polymer chains' interfacial interactions affect the way polymers crystallize. It was discovered that a variety of parameters, including particle surface charge, surface area, concentration, and dispersion, affected the nucleation impact of the nanofillers. Lattice matching and the polymer composite's processing parameters had an impact on nucleation as well. By increasing the crystallization rate, nanofillers lower the nucleation energy barrier. Nanofillers can also increase the polymers' degree of crystallinity. Polymers can be supplemented with a variety of nanofillers. The fillers in the polymer matrix can be uniformly dispersed to provide superior dielectric values and piezoelectricity. An improvement in polymer-based

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nanocomposites (NC)s' electroactive phases and dielectric characteristics makes compositematerials potentially useful for EH devices. Fig. 2 illustrates many techniques to improve the piezoelectricity of polymers.

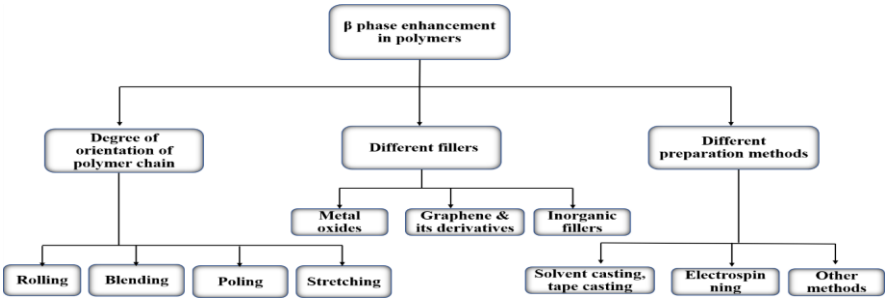


Fig. 2 Different methods for enhancing piezoelectric properties

PVDF/Metal Oxides

The piezoelectric characteristics can be enhanced by using different metal oxides. ZnO is the promising materials for piezoelectric devices [18, 19]. Because of their biocompatibility and adaptable growth, ZnO nanofillers were shown to be good materials for the construction of piezoelectric NGs [20]. A hybrid composite film was synthesized by combination of PVDF and calcium doped zinc oxide (CaZ). At 100°C, a temperature effect at 1 KHz frequency was discovered. For a 10wt% CaZ-doped PVDF composite, the dielectric permittivity was determined to be around 26.13 with a dielectric loss of 0.477 [21]. A flexible EH device was created by combining CaZ nanofiller composite material with PVDF-TrFE matrix. For the composite film, a saturated polarization of 1.32μC/cm^2 and a residual polarization of 0.604μC/cm^2 are produced. For composite film, a high coercive field value of over 41MV/m was found [22]. VDF polymer was used as the substrate in the fabrication of a piezoelectric NG, and ZnO was layered after PVDF coating. An electric potential of 7.63mV with a maximum displacement of 0.71 nm is obtained with a force of approximately 100N/m^2 [23]. After the preparation of the graphene-ZnO-based PVDF NC, its microstructure and morphology were examined. It was discovered that the PVDF nanofibers have enhanced piezoelectric characteristics, β phase, and crystallinity [24]. The nanofibers made from PVDF doped with zinc oxide (ZnO) and iron oxide (FeO) exhibit a piezoelectric output voltage (OV) of 5.9V for a 3wt% doped piezoelectric NG, which is 29.5 times greater than that of pure PVDF. For the hybrid composite, an increase in β-phase crystallinity of around 2.16% was observed. [25]. the addition of 0.85 volume percent. ZnO nanoparticles, with an average diameter of 50–150 nm, may increase the β-phase content in a PVDF matrix by up to 84%. At 50 Hz, the piezoelectric coefficient was discovered to be 50pC/N. For 1.7 vol%, the dielectric constant (ε) was recorded as 109 [26]. The ferroelectric PVDF-HFP crystalline β-phase in a co-doped ZnO filler was seen to grow as the concentration of nanofiller in the PVDF matrix increased. [27]. ZnO nanowires of around 50 nm in size were shown to improve the electric field and piezoelectric performance when added to the polymer matrix[28]. It was discovered that the PVDF/ZnO NC had better electrical output values than pure PVDF. The OV and current have increments of 2.7 and 6.5 times, respectively [28].

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Additionally, it was shown that the electroactive β-phase enhanced when ZnO-containing paper ash was used in electrospun PVDF nanofibres in place of traditional semiconducting fillers [29]. The inclusion of MgO nanoparticles containing rock salts smaller than 50 nm as fillers in PVDF-TrFE resulted in inhomogeneity non the electric field distribution in the composite because MgO's dielectric constant, which is 10, is like PVDF-TrFE's [30]. The important improvement in composites observed by adding MgO was recently reported to increase breakdown strength and impart a low leakage current [31, 32]. Enhancing MgO doped PVDF-TrFE composite film's ferroelectric and piezoelectric characteristics may help resolve the long-standing significant leakage current problem. Hydrogen connections between the F atoms of PVDF-TrFE and the −OH groups on the MgO surface develop when MgO is added. This new relate between the MgO and the polymer matrix was seen to increase the crystallinity [27]. With an increase of residual polarization, the value of the piezoelectric coefficient (d_{33}) increases. The NC film with 2wt% MgO/PVDF-TrFE had the greatest value, −65p.m./V. It was discovered that devices with pure PVDF-TrFE had d_{33} values of about -40p.m./V. By adding 2wt% MgO NPs to PVDF-TrFE, the piezoelectric coefficient was found to be 50% higher, demonstrating the effectiveness of MgO in improving superior ferroelectric and piezoelectric responses in polymer matrix [27]. Recent research reported on NiO@SiO_2/ PVDF NCs [30]. When metal oxide particles are added during the composites' manufacture process, agglomeration becomes a significant issue. NiO nanoparticles smaller than 100nnm are coated with non-conductive SiO_2 to prevent agglomeration and provide a conductive nanofiller channel inside the polymer matrix. When biomechanical force is applied, the piezoelectric NGs made of NiO@SiO_2/ PVDF are shown to be effective and have promising output characteristics. A high power density of 685W/m^3 together with an OV of 53V and a current density of 0.3μA/cm^2 was observed. For a 15wt% doping in polymer, a higher conversion efficiency of up to 13.86% was observed for the NiO@SiO_2/PVDF NC. To create PVDF-based NGs for EH and storage applications, metal oxide TiO_2 is another fantastic semiconductor [26]. A wearable, flexible NG can be made to capture mechanical energy from daily actions.

PVDF/Graphene Oxide and its derivatives

The ε and piezoelectric constant values may be increased by adding conductive fillers to the composite materials, causing micro-capacitors to develop inside them. Additionally, conductive fillers help to stabilize the polymer matrix's polar β-phase [33]. For composite-based PENGs to provide good yields, the filler particles must be uniformly dispersed throughout the polymer matrix. It guarantees that the energetic energy-harvesting composite layer's piezo potential is distributed throughout [34]. a self-powered, flexible piezoelectric sensor made of graphene-doped PVDF nanofibers (PES). Given that PES is very sensitive to pressing and bending, a steady link between bending angle and piezoelectric voltage was discovered [35]. Many polyaniline (PANI) and reduced graphene oxide (rGO) doped PVDF NGs were created. The rise in the piezoelectric β-crystalline phase of PVDF during electrospinning is confirmed by the findings of FTIR and XRD analysis. For rGO-doped PVDF and rGOPANI-coated PVDF nanofiber, the maximum OVs were seen to be 7.84V and 10.60V, respectively [36]. When 0.05 weight percent of graphene was added to PVDF, the thin film's β-phase content increased to 67.30%. PVDF thin films were created by

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intercalating graphene with an auxiliary electric potential (voltage) during the direct ink writing procedure [37]. A clever membrane with electrical response that is created by combining graphene and PVDF. A high graphene concentration causes PVDF toself-assemble, giving rise to a high β-phase content and a special self-piezoelectric characteristic. The membrane also exhibits unique capacitive characteristics and excellent electrical conductivity [38]. GO-doped PVDF was electrospun to create nanofiber mats. It was discovered that adding 2 weight percent of GO to the PVDF matrix enhanced the β phase content. With an Open circuit voltage (OCV) of 1.5V and a short circuit current (SC) of 200nA, the polar phase reached its maximum at 2wt%. At 140°C, rGO may be produced from GO using various reducing agents, resulting in a greater β-phase content. The performance of electricity generation greatly improves with the installation of rGO. The results showed that the open-circuit voltage was 16V and the short-circuit current was 700nA [39]. By using electrospinning, graphene-ZnO/PVDF NC nanofibers were created. With an increase in crystalline and polar β phase, a significant improvement in piezoelectric characteristics was observed. Peak-to-peak voltage of around 840 mV was measured for PVDF/G-ZnO nanofibrous composites when 1N of applied force was used. PVDF/ZnO nanofibers produced a higher OV (710mV) than pure PVDF (640mV) [40]. According to research, rGO is the best option for piezoelectric NGs that are utilized to harvest energy from a PVDF or PVDF-TrFE matrix [41]. In the composites, rGO incorporated in the polymer matrix has two main functions. In composites, rGO helps to align the dipoles and produce micro-capacitors inside the polymer matrix. In the basal plane of rGO, there are many oxygen functional groups, including carboxyl and carbonyl groups. These functional groups enhance the polymer composite's crystallinity and make it easier for dipoles in polymer chains to align by aligning fluorine atoms on one side [28]. In composite materials, an increase in rGO content was shown to improve the dielectric constant [42]. When rGO flakes are added, the dielectric constant of pure PVDF-TrFE thin films rises to 72 at 1KHz from 35. The creation of local capacitor electrodes in the PVDF-TrFE layer may be the cause of this rise in the dielectric constant. An important factor contributing to the rise in capacitance in composites is the development of micro-capacitors. Improvement in the dielectric constant because of the dipoles in the polymer matrix aligned in a single direction [42]. The impact of graphene nanoplatelets on the electrical output, polymorphism, and crystallinity of the PVDF matrix was observed. By adding 0.1% graphene, the OCV for pure PVDF which was 3.8V was raised to 7.9V [43]. Gr-Ag-doped PVDF hybrid NC was prepared in a single pot, which was thought to be a more economical way of creating NGs [44]. For the piezoelectric NG, a uniaxial compressive stress of about 5.2kPa was observed at a current of 0.1nA and an OV of 100mV. It was discovered that the Fe-doped rGO NC integrated into the PVDF matrix had an enhanced γ-phase. A portion of the $–CH_2–$ dipoles, which are made up of –CH2–CF2–chains in PVDF, are drawn to the π-electrons of rGO. Chromoxide dipoles are repelled by iron oxide/fe/Fe particles bonded to the rGO matrix. In a similar vein, the Fe/iron oxide particles attracted $-CF_2–$ dipoles in PVDF. The $-CF_2–$ dipoles are repelled by the delocalized π-electrons seen in rGO [43]. Fe-rGO has a variety of functional groups that include carbonyl, carboxyl, and hydroxyl groups that include oxygen. These groups can form hydrogen bonds with PVDF's fluorine or hydrogen atoms. Furthermore, when mechanical stress is applied, a phenomenon known as stress-induced polarization occurs, which causes an

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electric potential to emerge in the polymer matrix and align all the dipoles in the same direction [45]. OCV of 2.4V and short-circuit current of 0.8mA are recorded in PENG when 2N force is applied when 0.1% rGO is added to PVDF. Furthermore, it was shown to have a maximum output power of 3.2μW when the load resistance was 1.8 MΩ. Without using the poling technique, all outputs were recorded [42]. At the maximum applied stress, 0.45V, approximately five times greater than pure PVDF, was produced with 1% filler [46]. A PVDF matrix loaded with 1% graphene nanohybrid produced an output signal of 14μW/cm3 under applied stress. In the polymer matrix, a linear connection between the applied stress and the polymer is caused by the alternating orientation of polarization chains, which gives birth to the α phase in PVDF. PVDF chains were discovered to have a zigzag structure, with CH_2 groups arranged downward and CF_2 groups oriented upward. The oxygen functions in GO lamellae give rise to this kind of interaction. Rapid solvent evaporation was seen to have an impact on the alignment and distribution of the GO lamellae. During the electrospinning process, nanocrystals are discovered to be developing in PVDF, which causes the GO lamellae to transfer to the nanofiber surfaces. There are other places where the π-electron delocalization in GO and the $-CH_2/-CF_2$ dipoles of the PVDF interact [49]. It is discovered that one crucial factor in conductive fillers is the surface area. The fraction of the β phase in the polymer matrix will increase with the surface area of the conductive filler. FTIR spectroscopy was used to analyze the vibrational modes caused by the chemical interactions between the polymer and the core shell structure. The C-H bending vibration band at 880 cm^{-1} was increased by the electrostatic interaction between the $-CH_2$ dipoles of PVDF and the delocalized π electrons in GO. PVDF composites made by electrospinning and doped at different concentrations (0.05–3.2wt%) with GO and Gr as nanofillers. A high concentration of GO doped PVDF showed an increased polar β phase. Comparing the PVDF/GO and PVDF/Gr composites to the Hal nanotubes, the latter possessed rod-like morphology and more aligned and finer nanofibers. Nevertheless, while having a lower β-phase percentage than graphene-based composites, the PVDF/0.8 Hal composite was shown to have a greater OV (0.1V). It was established that a wide range of variables can influence the piezoelectric response. In addition to other significant parameters like the relative orientation and fineness of nanofibers, the dielectric constant and β-phase may be used to calculate the piezoelectric constant [50]. A notable rise in the β phase was observed, rising from 77% to 83% when 0.1 weight percent graphene was electrospun into the PVDF matrix. When graphene is added more than a particular amount, the β-phase decreases to a maximum of 75%. After 0.1% graphene was added to PVDF/Graphene nanofibers, the open-circuit voltage increased from 3.8V to 7.9V [43]. PVDF-HFP NCs and rGO nanosheets were synthesized, and various analyses were conducted on them, including mechanical strength, dielectric characteristics, shape, and structure [51]. Because of the spin-assisted preparation procedure, rGO nanosheets were shown to be well dispersed in the polymer matrix. At 100 Hz, the dielectric constant value of 54 was found to be four times greater than that of pure PVDF-HFP. After adding 0.7 vol% graphene with a dielectric loss of 0.27, a higher dielectric constant value was attained. The rGO nanofillers in the polymer matrix can be well-aligned and dispersed to provide a high dielectric constant value. In PVDF NCs, it was discovered that the shear stress during the spin coating process affected the alignment of the rGO nanosheets. Spin-coating speed is a useful tool for controlling thickness. The thickness of the film increases with slow spinning

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speed and decreases with high spinning speed. The composite's percolation threshold rises because the rGO sheets are aligned, and this may be utilized to create low dielectric loss materials. [52]. Research has also been done on the synergistic impact of piezoelectricmaterials that contain more than two components in a piezopolymer matrix. Improved piezoelectric responses and energy-harvesting capabilities result from synergistic effects. In a tri-layer PENG, an additional PVDF-BTO film layer positioned between the electrode and graphene served as a blocker to stop the charges from recombining. Both the top and bottom surfaces of the graphene have persistent charges. The orientation of the dipoles in graphene on both sides was shown to be significantly influenced by these persistent charges [52].

With an increase in tensile stress and dielectric constant, it was discovered that the inclusion of graphene layer raised Young's modulus and piezoelectric constant d_{33} [52]. When AlO-rGO is added to PVDF, it acts as a nucleating agent and raises the electroactive β-phase up to a particular amount. The PVDF matrix contains well-distributed AlO-rGO nanosheets that create a conductive network. The charges are drained toward the steel fabric electrode via this conducting network. These drain charges are a major factor in enhancing the EH piezoelectric characteristics. It was discovered that the PVDF/AlO-rGO-based NGs outperformed generators made with pure PVDF using conventional electrical poling. For the NG, a notable rise in the open circuit OV of 36V and a SC of 0.8μA were observed. For repetitive human finger pressure, a high-power density of 27.97μWcm^{-3} was observed. For PVDF-based PENGs, these are the greatest output levels that have been documented. A piezoelectric NG composed of BTO nanoparticles loaded in PVDF and 0.15wt% Gr nanosheets was created using nanofibers. Electric power was recorded at 2 Hz frequency and an open-circuit voltage of 11V at a strain of 4mm. After 1800 cycles, the piezoelectric NG's open-circuit voltage did not change, indicating its durability. Furthermore, a peak voltage of 112V was observed when pushing and releasing the finger. This PENG can power an electronic watch and 15 LEDs. The enhanced output is attributed to the combined action of graphene nanosheets and BTO nanoparticles. It was discovered that the NC fibers increased PENG's overall performance [53]

PVDF/CNT

It has been discovered that CNTs are more promising reinforcing nanofillers for composite materials due to their exceptional characteristics. Because of their remarkable features, including their high aspect ratio and low mass density, CNTs are a great choice for chemical functionalization. CNT integration in a composite structure can improve the electromechanical and electrochemical characteristics for sensing transduction processes [54, 55]. A composite material consisting of PVDF, MWCNT, and lead zinc doped lead zirconate titanate (PLZT) was used to create the hybrid piezoelectric NG. An AC open circuit value of 20V was measured from peak to peak. By exerting pressure with its foot, the PENG was able to charge a 40μF capacitor and produce 1.5mW of power using a 6V DC voltage and 250μA of SC [56]. With a dielectric constant of 3.6 and a suitably elevated strain, the CNT-doped PVDF produced a geometrically restricted nanostructure. Bending actuation increased by 38% and piezoelectric voltage by 250%. β-phase concentration was 18% higher than that of

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solid nanofibers. From 450 mV/N, sensitivity rose to 108% at 940 mV/N. By adding 0.05wt% of CNTs into the PVDF matrix, there was a noticeable 21% improvement in piezoelectric actuation, from 14.8μm to 18μm. A noteworthy rise in β-phase and a total elimination of α-phase were seen, accompanied by a 45% increase in crystallinity. Elastic modulus of a polymer composite can increase by up to 263% in a hollow structure [57]. Tensile strength was improved and mechanical and piezoelectric characteristics were noticeably increased when 0.008 weight percent MWCNT was added to PVDF. Additionally, when the concentration of MWCNT in the polymer matrix rose, it was discovered that the β-phase of the NC improved in thermal stability [58]. During the electrospinning process,MWCNTs align themselves with the PVDF's axial direction, and it is discovered that the nanofibers' β-phase content has risen. Improvements were also made to the mechanical, thermal, and crystallinity qualities. When an electric field of 4V/μm is applied, the actuators made of 1.5wt% MWCNT in PVDF exhibit excellent actuation bending around 24μm [59]. Both the acidified and unacidified MWCNTs are implanted in PVDF, and their respective effects are examined. A COOH functional group was used to adorn the acidified MWCNT. An XRD analysis revealed that in both acidified and unacidified MWCNT, the β phase was elevated. However, because PVDF and MWCNT have strong interfacial contacts, acidified MWCNT was shown to have greater mechanical strength. With a 12wt% addition of MWCNTs-COOH, tensile strength increases to 64.6 MPa, which is 24% greater than with pure PVDF. For 12 weight percent MWCNT in PVDF, the dielectric constant increased to 286, ~36 times more than in naked PVDF for unacidified MWCNT. Local conductive networks increase the dielectric constant, which promotes electron displacement polarization in the polymer matrix [60].

The technique of ultra-sonication has been proven to be effective in improving the β phase of melt-cooling and melt-spinning solutions. For composite films, sonication can be used to mix the solution more evenly [61]. By increasing the piezoelectric constant, the CNT fillers function as an electric conductive filler in PVDF between the $–CH_2–$ and $–CF_2–$ electric dipoles. After CNT doping in a PVDF matrix, the voltage was raised to 30% and the current to 96%. It was discovered that spin coated films with a diameter of 8.5 nm and a length of 1.5μm, produced with 0.7wt% CNTs in PVDF, increased and mixed with the α phase. Whereas the α phase is nonpolar in nature, the γ-phase is polar. The γ-phase's d_{33} value was discovered to be 13 p.m./V [62]. Spray coating was used to create CNT/PVDF films with a 0.0075wt% CNT doped PVDF; the output power was recorded at 0.015 [63]. When CNT/PVDF nanofibers were created by electrospinning, many authors have confirmed that the synergistic impact improved some attributes, including crystal structure, dielectric constant, and piezoelectric performance. Dipole movement is improved by electrospinning in the same direction and β phase. Functionalization and mechanical stretching are two alternative techniques to enhance the piezoelectric characteristics of composite materials [67]. According to recent research, PVDF can achieve a 100% β phase with CNT modification and reinforcement. Modification of CNT by functional groups such as -OH hydroxyl groups [69] and -COOH carboxyl groups [68] can enhance some other characteristics. Additional functional 3,4,5-trifluorobromobenzene (TFBB) [70] and amino (-NH2) [71] have been shown to boost nucleation efficiency and improve CNT dispersion in a polymer matrix. It was discovered that the β-phase has superior mechanical characteristics.

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Good dispersion of CNTs in polymer composites results in notable improvements in ferroelectric, pyroelectric, and piezoelectric characteristics [72].

Due of the fillers' high conductivity, a significant drop in breakdown strength was seen in the CNT/PVDF composite. The piezoelectric performance of CNT-doped PVDF cannot be further altered since it cannot be poled in an adequate electric field. Therefore, the proper way to get around this problem is to orient the fillers perpendicular to the applied electric field [73]. Numerous writers have looked at how CNT affects different composite material qualities. There is a noticeable improvement in the β-phase and crystallization of PVDF or copolymer. It is discovered that the β-phase in PVDF-TrFE is aligned with the long axis of the CNTs [74]. It was found that by adjusting the CNT's axis orientation, the dipole orientation within the polymer could be adjusted. When the CNT axes are aligned parallel to the substrate, the maximal propensity of β-phase alignment along the polar axis is observed to be directed perpendicular to the substrate. When the films are deposited using solutioncasting and mechanical rolling techniques, the degree of orientation may be increased more effectively [75]. The highest degree of orientation was seen when PVDF-embedded TiO2-coated CNTs were used. TiO_2-coated CNTs with a diameter of 40–60 nm and a length of 5–15 mm were found to be more aligned than PVDF domains. For 0.3wt% of filler, the piezoelectric coefficient was found to be around 41pC/N, which is double that of pure PVDF. The greater OV was discovered to be caused by a higher β phase in fibers generated via electrospinning. Maximum β phase was discovered in composites made by CNT/PVDF, but smallest β phase was reported in PANi/PVDF [76]. The greatest OV measured for CNT inserted into PVDF composite was 0.9V, whereas the minimum was around 0.46 V for composites containing PANi. According to research, the composite materials' OV arrangements for the various additives are as follows: CNT > LiCl >rGO > pure PVDF > ZnO > PANi [77]. PVDF is combined with inorganic fillers to create a polymer NC, and the resulting co-polymers show great promise for energy-harvesting devices.

PVDF/Salts

The impact of salts on the piezoelectric characteristics of PVDF and its co-polymers was investigated by several researchers. After adding salts, it is discovered that structural and dielectric characteristics change [78–85]. It was discovered that adding magnesium chloride hexahydrate salt (MgCh~$6H_2O$) at various weight fractions to PVDF-HFP film made using a solution casting technique enhanced the film's flexibility. A higher $MgCl6H_2O$ salt concentration lowers the film's crystallinity and Young's modulus. 1wt% MgCh2 produced a β phase that was 87.2%, four times greater. Comparing the composite to pure PVDF-HFP, $6H_2O$ was added. At 10Hz, a dielectric constant of 19.2 was observed for a 4wt% $MgCh_2.6H_2O$ filler [80]. Lithium salts and PVDF-HFP were able to effectively replace the liquid electrolytes in Li-O_2 batteries with gel-polymer electrolytes. Lithium salts have the electrochemical performance to produce gel polymer electrolyte (GPE) [81]. Cerium (III)/yttrium (III) nitrate hexahydrate significantly alters the dielectric constant and β phase in PVDF [82]. The addition of $ErCl_3$ or $GdCl_3$ and lanthanum (III) chloride ($LaCl_3$) to the PVDF was investigated for its dielectric characteristics, respectively [83]. The piezoelectric constant for thin films of erbium (III) chloride hexahydrate at 5wt% and iron nitrate (III) nonahydrate

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at 10wt% −72.4pC/N, respectively, were determined [84]. After adding cerium (III)-N, N-dimethylformamide-bisulphate [Ce(DMF)$(HSO_4)_3$] to the PVDF, higher β and γ phases were formed approximately 99% of the time [85]. When a human finger is tapped on a PENG made of non-electrically poled cerium (III)/PVDF, the OV is found to be 32V. Due to the formation of a self-poled electroactive β-phase, electrostatic interactions between the fluoride of PVDF result in a high electrical output. The interaction between the opposing charges of the cerium and PVDF, as well as the formation of a positively charged surface through H-bonding and bipolar contact, may result in a high output. Erbium (III) chloride hexahydrate doping raised the OCV to 115V and the SC to 32μA in PVDF. For the PVDF NC doped with erbium (III) chloride hexahydrate, power density improved to 160 mW/cm3. The OV and current of the iron nitrate (III) nonahydrate doped PVDF NG may climb to 75 V and 17μA, respectively. Iron nitrate (III) nonahydrate doped polymer composite was discovered to have a power density of 55.34mW/cm^3. In PVDF composite film doped with ytterbium (III) chloride hexahydrate, the piezoelectric constant and β-phase rose by up to 80% [86]. The composite film exhibited an OCV of 10V and a SC of 63μA with the application of 0.17 MPa pressure. Numerous researchers have looked at piezopolymer composites doped with various ions, such as Eu^3+, Zn^2+, Mn^2+, Ce^3+, and Al^3+ [87–90]. Without any mechanical stretching or electrical poling, the piezoelectric characteristics are improved by the addition of various fillers. The crystallinity of melt-electrospun PVDF was shown to be significantly impacted byorganic filler [91]. The high degree of β phase improvement up to 150% was attributed to the filler materials' strong bond with the polymer chains. Due to hydrogen bonding and the interfacial polarization between filler materials and the piezoelectric output, dielectric characteristics were also enhanced. The piezoelectric coefficient d_{33} for the Al $(NO_3)_3 \cdot 9H_2O$ doped PVDF composite was found to be −116 p.m. V^{-1} at 10wt% doping. It was discovered that the dielectric constant increased for various filler and polymer matrix compositions [90]. It was discovered that the piezoelectric coefficient declined when the crystallinity and dielectric qualities deteriorated at a given concentration.

PVDF/Metal nanoparticles

Metal nanoparticles can be added to polymer composites to improve electroactive polar phases and create nucleating agents. Due to their interfacial interactions with PVDF, metal nanoparticles—inorganic particles—improve the β phase. Comparable improvements were seen in various functional characteristics including piezoelectric performance of PVDF with organic fillers. When 100 nm-diameter silver nanoparticles were introduced to a PVDF matrix, the amount of electroactive phase increased [92]. It was possible to construct a polymer NC film doped with varying quantities of palladium nanoparticles (PdNPs) using a combination of PVDF and Poly(vinyl Chloride) (PVC). After adding PdNPs, PVDF/PVC was shown to have improved electrical conductivity [93]. Free-standing flexible Fe-doped ZnO (Z (1-x) F(x) O)/PVDF-TrFE NC films with x = 0.05 were made, and it was shown that the composite film had improved piezoelectric characteristics with a 7 V OV, a residual polarization of 0.125μC/cm^2, and a dielectric permittivity of 21.03 at 1 kHz [94]. The Ag/PVDF fibers were produced using electrospinning and shown to be successful in both piezoelectric and bactericidal investigations. The OV of the PVDF was found to be about 2 V when Ag was added at 0.4 weight percent. Research on platinum nanoparticles doped in

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PVDF-HFP matrix revealed noticeably enhanced piezoelectric characteristics [95]. When porous Ag was implanted in PVDF-HFP, it was discovered that the residual polarization climbed to 61.7μC/cm^2 and the piezoelectric coefficient d_{33} to −686pC/N improved well. At one kHz frequency, it was discovered that the dielectric constant had grown to 2678 and the dielectric loss to 0.79. Upon applying about 4Mpa of compressive stress on PENG, an open-circuit voltage of approximately 18V and a short-circuit current of 17.7μA were observed.

Energy-Harvesting Applications

A highly sensitive flexible piezoelectric NG based on PVDF-HFP supplemented with graphene quantum dots (GQDs) has been disclosed. very high output current of 25nA and OV of 6V It was discovered that the signal produced by the pure PVDF-HFP NG was inferior to that of the flexible transparent piezoelectric NG made from the GQDs/PVDF-HFP composite film [96]. The flexible PVDF hybrid material-based matrix motion sensor's output performance was examined. At a frequency of 3Hz and a force of 300N, the NG's OV of 15mV was discovered [97].

Greater open circuit current and a greater OV are confirmed by a higher β phase in the composite material. A more efficient PENG gadget will have a higher power density. Numerous elements have been shown to influence PENG's energy-harvesting performance. The parameters of an EH device are significantly influenced by the dielectric constant and dielectric loss. High dielectric constant and low dielectric loss composite materials based on PVDF have been discovered to be excellent candidates for PENG. High-quality piezoelectric characteristics improve EH devices' output performance. Composites based on vitamin B2 were produced for EH applications in PVDF at different concentrations [98].

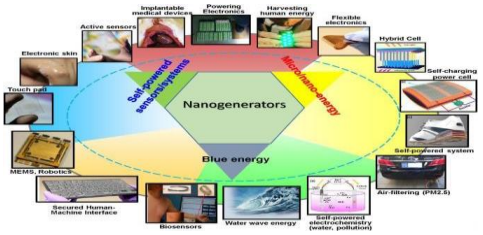


Fig. 3 Applications of piezoelectric material ref. 95

Forty five weight percent of vitamin B2 in PVDF, a maximum β-phase of 93% and a piezoelectric coefficient of -50.3pC/N were found. Outstanding power density of 9.3mW/cm^3 was reported for PENG, with an open circuit current of 12.2μA and an OV of 61.5V. This NG can illuminate over 100 LEDs. At 3wt% of CTAB-MMT (CM), the dielectric permittivity was discovered to be 48 [99]. With an increase in dielectric constant, the modified CTAB improved the piezoelectric constant d_{33} to 62.5pC/N. The power density of the piezoelectric device made of this composite material is 50.72 mW/cm^3. composites based on PVDF and PZT that are made in two steps. For composite material, first a nonsolvent-induced phase separation and then hot-pressed were used [100]. The composite materials used to construct the PENG have a high OV of 1.71V and a SC of 34.83nA. For pressure sensing devices, PVDF/ZnO nanofibers produced by the electrospinning process with a cowpea-structure were shown to be more flexible and self-powered [101]. The addition of 5 weight percent ZnO was shown to improve the β phase. For PES, a high sensitivity of 0.33V kPa^{-1} with a reaction time

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of 16ms was observed [102]. The crystallinity and β phase were found to be highest in wrinkled fibers and lowest in porous fibers. The pillar wrinkled surfaces with high roughness levels of the wrinkled fiber led to greater electrical outputs, which in turn caused a rise in the β phase, interior pores, and friction ratio.

Discussion

Compared to bare polymers, piezoelectric PVDF and its copolymers have been discovered to be excellent candidates for EH due to their high strength and exceptional flexibility. Composite polymers are inexpensive and simple to work with for creating self-powered gadgets. There are several industrial uses for composite materials. Composite materials may be used more effectively to build sensors and actuators. This study summarizes many approaches that may be used to improve the sensing capacity and piezoelectric constant of piezoelectric sensors and NGs based on PVDF. PVDF-based devices can enhance the β phase's crystallinity and increase their piezoelectric coefficient by employing appropriatefillers and processing techniques. Numerous efforts have been made to improve PENG's energy-collecting and sensing capabilities. One of the most important scientific advances in understanding piezoelectric characteristics is the comprehension of the effects of various fillers on piezopolymer composites. The addition of fillers with various functions to the polymer matrix is essential to improving EH and piezoelectric performance. PVDF-based piezoelectric devices are in demand despite a variety of problems because of their high output and remarkable adaptability. PENG devices are inexpensive, easy to build, and have great output performance and stability when used on an industrial scale. Newly discovered materials with improved characteristics and innovative architectures are gradually used to fabricate gadgets. By using mechanical energy conversion in the future, flexible PENG is thought to be able to satisfy the practical application needs for sustainable energy devices.

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PARAMETRIC CHARACTERISTICS OF HYDROGEN-DIESELDUAL FUELENGINE-A REVIEW

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ABSTRACT
In order to examine the most feasible hydrogen energy share in a dual fuel engine at various compression ratios, a numerical model was created to assess the combustible and emissions parameters of the internal combustion engine.A port fuel injector is used to introduce hydrogen through the intake port (PFI). Every study changes the compression ratio by 15.5, 16.5, and 19.5%. The percentage of energy derived from hydrogen varied from zero percent to fifty-five percent. The results show that there is a definite trade-off between compression ratio and maximum hydrogen energy sharing. When the compression ratio (CR) was lowered from 19.5 to 14.5, the optimum energy from hydrogen share increased from twenty percent to forty-five percent, subject to knock-on limitation. At all compression ratios, emissions of all kinds except NOx seem to drop as hydrogen's energy content rises.

Investigating the use of hydrogen as fuels for low-load diesel engines is the aim of this project. As hydrogen auto-ignites at temperatures that are higher than diesel fuel, it cannot be used in an engine powered by diesel right away. The alternative induction or enrichment technique is hydrogen. In a single-cylinder research engine, diesel fuel has been converted to hydrogen in order to study the combustibility characteristics of this dual fuel engine.

For the hydrogen to reach the combustion area, a mixer had to be used to add it to the entrance manifold. The engine was operated with a 10 Nm load and 2000 rpm continuous speed. At flow rates of 21.4, 36.2, and 49.6 liter/min hydrogen was added. Investigations were conducted intocylinder pressure, suggested efficiency, and specific energy consumption.The engine's efficiency and the peak pressure of the cylinder were both decreased by the hydrogen improvement at this low load.

KEYWORDS
Diesel; hydrogen; dual fuel; combustion; CFD; knock-low temperature; combustions; emission.

1. INTRODUCTION
CI engines are widely utilized in hauling and transporting applications because to their strong construction, improved low-end torque, and remarkable fuel efficiency. However, the uneven character of typical diesel combustion may be the cause of the increased nitrogen oxides and emissions of soot from diesel engines [1]. In the realm of internal combustion engines, lowering emissions and increasing combustion efficiency have long been top priorities.Over time, a plethora of complex techniques have been created to address the issues related to traditional diesel combustion. The RCCI, PCCI, HCCI, and LTC are some of these technologies [2].

Nevertheless, the majority of these technologies are not intended to be utilized with the engines

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that are presently in use and instead call for specialized engines with greater combustion control. Conversely, the dual fuel technique requires less engine modification and is an inexpensive way to increase combustion performance in a normal diesel engine [3, 4].The consumption of the hydrogen as fuel in engines that burn gasoline has advanced significantly in the present year. In the past ten years, a lot of research has been done on the use of hydrogen as a fuel supplement in diesel-powered CI engines. Because of its many advantages, hydrogen can be used as fuel in engines that use gasoline [5-7]. The percentage of hydrogen in dual-fuel engines has increased. Better fuel injection techniques that provide greater control over the rate and phase of combustion are the source of these improvements.Hydrogen has several benefits that make it suitable for use as fuel in internal combustion engines [5-7]. Table 1 compares the main characteristics of combustion between diesel and hydrogen.

During port injection, optimal air premixing is made possible by high hydrogen diffusivity. Such premixing enhances the uniformity of the charge inside the cylinder by lessening the heterogeneous character of the CDC. Burning hydrogen with slow-burning fuels like diesel increases the thermodynamic efficiency of the fuel due to its faster flame.

Because of its wide range of flammability (4–74% by volume), hydrogen can be used in thinner mixes to facilitate low-temperature combustion (LTC).

Table1

SIGNIFICANCE FEATURES OF DIESEL AND HYDROGEN

PROPERTIES	Hydrogen properties	Diesel Properties
Lower Heating Values (MJ/Kg)	44	121
Stoichiometric Air Fuel Ratio	14.6	34.3
Energy Density @15^{0}C And 100KPa, MJ/m^3	35.7	10.2
Auto Ignition Temperature (K)	531	857
Laminar Burning Speed (m/s)	0.4	2.64-3.24
Limits On Flammability (%Volume in Air)	0.8 to 04.9	4 to 76
Density @15^{0}C And 100KPa, MJ/m^3	849	0.0084

Utilizing hydrogen as a fuel in a vehicle with internal combustion has several advantages. It is highly combustible, odorless, low-polluting, and renewable over an extended period of time.Some of hydrogen's other characteristics, like its low density, short quenching distance, and low ignition energy, would be difficult to overcome before using it as fuel for engines with internal combustion [8]. The diesel-hydrogen twin fuel engine reduces smoke pollutants and improves brake thermal efficiency by consuming less fuel than a typical diesel engine.

Furthermore, NOx emissions were decreased, i.e., when full load operation was not used [9]. Hydrogen induction produced notable reductions in smoke production, the ignition tardiness, extremely high maximum pressure rates, and fuel efficiency, especially when the fuel share exceeded 15% [10]. When exhaust gas recirculation (EGR) is used in combination with dual fuel, the brake thermal efficiency is higher than when diesel is run effectively. Dual fuel operation produced the least amount of unburned HC and smoke when there was no EGR. EGR effectively reduced emissions of NOx [11].

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2. The characteristics of Combustion

At compression ratios of 14.5, 16.5, and 19.5, the combustion characteristics are displayed using pressure and heat discharge rate in addition to combined heat release variation with crank angle. The figures 2, 3, and 4 are shown. An increase in the hydrogen share has an effect on these. The rate of hydrogen reaction (HRR) and the timing of ignition usually rise in tandem with a rise in the amount of hydrogen energy share. Up to a 20% hydrogen share, a compression ratio (CR) of 19.5 (Figure 2(a) and (b)) improves the combustion of hydrogen and diesel and lowers ignition delay.By 1.05% above the case of 0% HES, the gIMEP increases to 20% HES before declining. The first increase is due to homogenous combustion, which is facilitated by premixed hydrogen. The result of fast hydrogen combustion, which happens over 20% HES, is knocking.

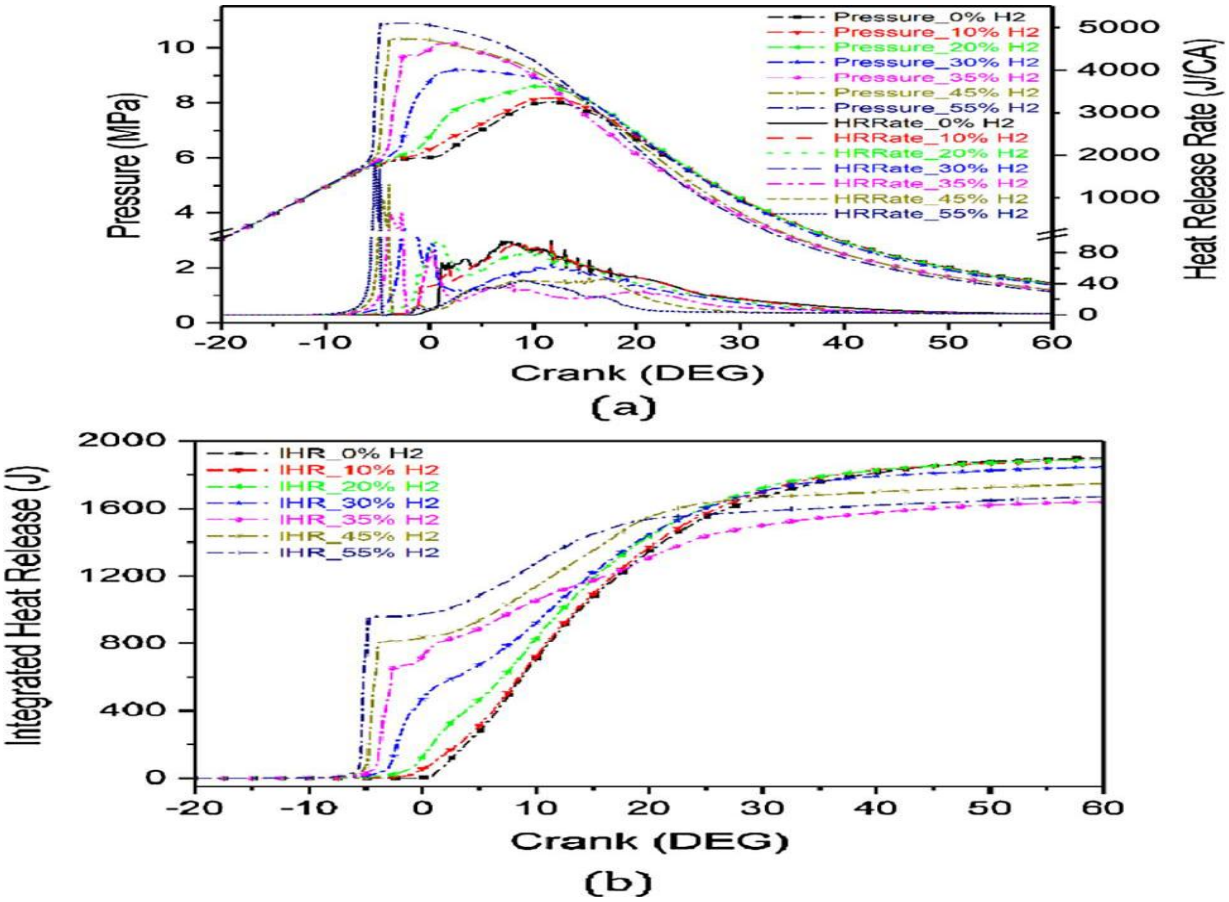


Figure 2. (a) At a pressure ratio of 19.5, the in-cylinder pressure, heat release rate, and (b) integrated heat release is plotted against the degree of CA using hydrogen energy share.

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The temperature and pressure inside the cylinder during the compression stroke tend to be higher at this compression ratio, which accelerates the burning of the hydrogen. Diesel burns at a lower rate of spontaneous full combustion than hydrogen due to the higher pressure and denser packing of hydrogen molecules. The IHR traces in Figure 4(b), which show that for cases where the HES is more than 30%, the majority of the IHR is centered at TDC, provide support for this conclusion. Because hydrogen burns more quickly than diesel, there is less air available for diesel to burn. gIMEP falls as a result of reduced combustion efficiency brought on by oxygen competition.

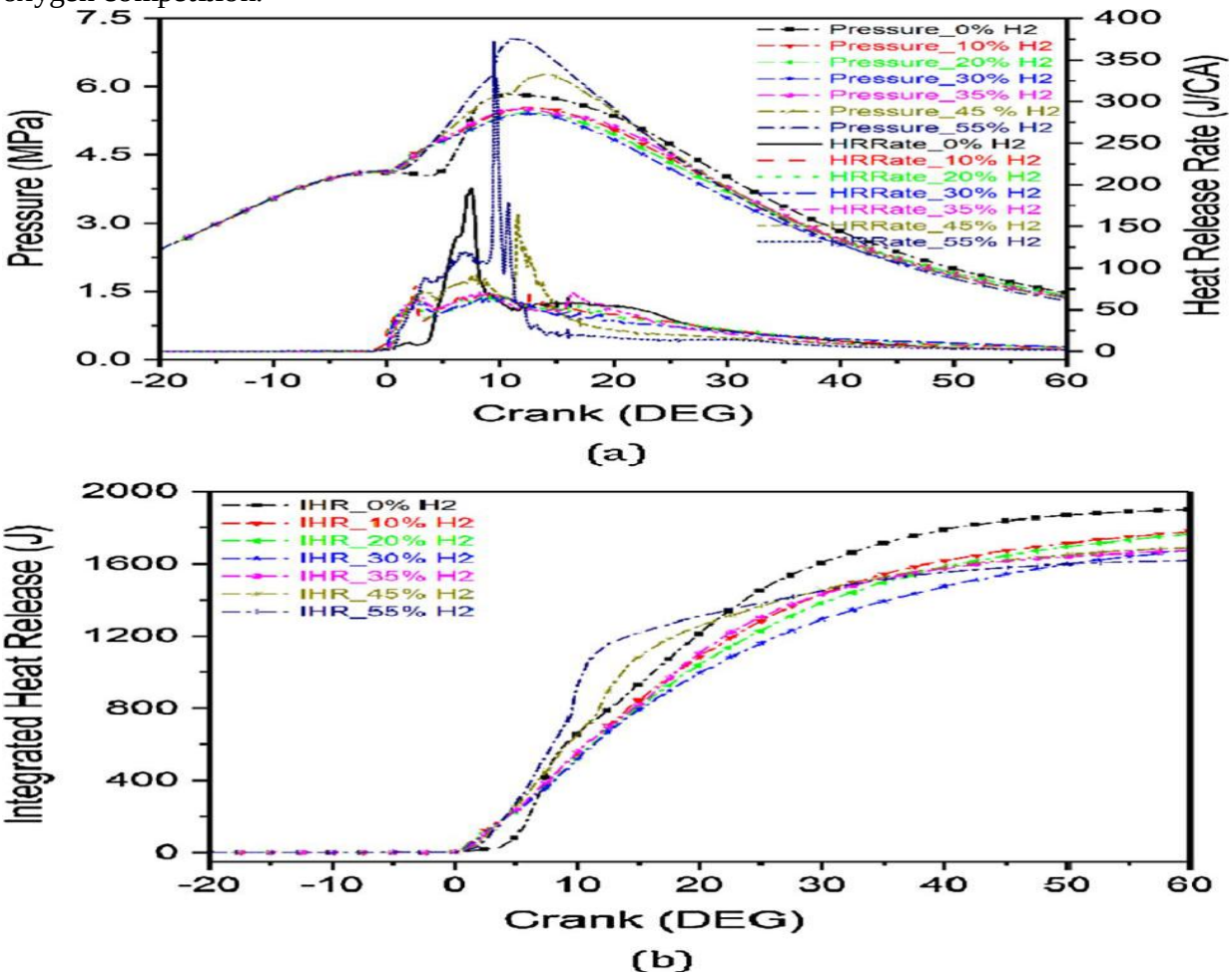


Figure 3. (a)At a pressure ratio of 14.5, the inline cylinder pressure, heat release rate, and (b) integrated heat release is displayed against the degree of CA as the hydrogen energy share increases.

Higher flame speeds, better hydrogen combustion efficiency, and homogenous combustion are responsible for this increase in gIMEP. The integrated heat dissipation footprints, pressure, and

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heat loss rate for a 16.5 compression ratio are displayed in Figures 4(a) and (b). The gIMEP increases by 0.9% at 30% hydrogen share after first remaining constant at 0% hydrogen share up to a hydrogen energy share of 20%. This improvement in gIMEP can be attributed to increased flame speed, homogenous combustion, and peak hydrogen combustible efficiency.

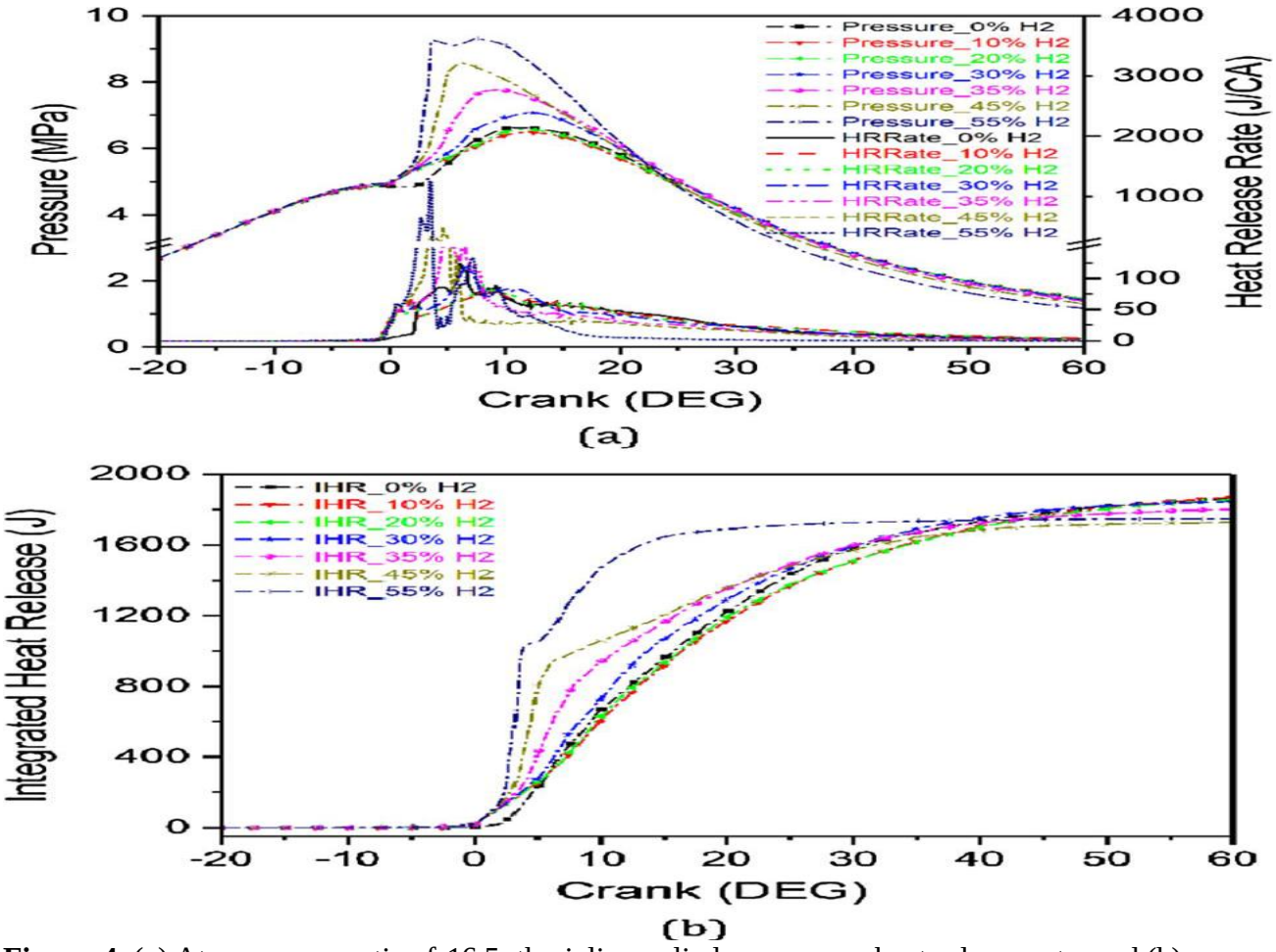


Figure 4. (a) At a pressure ratio of 16.5, the inline cylinder pressure, heat release rate, and (b) integrated heat release are displayed against the degree of CA.

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3. CONCLUSION

This work uses three-dimensional closed cycle sector numerical modeling to study parametrically the impacts of HES and ratio of compression on a dual combustion of fuel and emission levels. The investigation's findings led to the following conclusions:

- The findings indicate that the maximum HES is significantly influenced by the engine's CR. Although higher HES can be attained at lower CR values, lower pressure and temperature conditions cause diesel combustion to become inefficient at CR less than 14.5.
- Knocking is a significant element that is responsible for the growth in HES. At greater CR, the probability of knocking increases with rising HES.
- Within the knock limit, there is an apparent reduction in emissions of HC, CO, and soot, but a rise in NOx levels.
- Within the knocking limit, higher HES enhances combustion characteristics and encourages more uniform burning of the charge.
- The investigation revealed that the optimal HES levels for compression ratio 14.5, 16.5, and 19.5, respectively, were found to be 45%, 30%, and 20%.
- At Compression ratio 14.5 with HES 45%, soot mitigates by thirty-seven percent and oxides of nitrogen enhances by eleven percent.
- In tandem, NOx increases by 27% and soot decreases by 83% at CR 16.5 with 30% HES and only 3.5% and 61%, respectively, at compression ratio19.5 with 20% HES.
- At CR 16.5, the decreases in HC and CO are 36% and 69%, respectively, and at the CR 19.5, 93% and 80%.

These findings point to specific trade-offs between soot, HES, compression ratio, and oxides of nitrogen (NO) in dual fuel combustion engines that run on both hydrogen and diesel. The study's trade-off parameters can be further adjusted to achieve effective, eco-friendly, and knock-free burning in a hydrogen-enriched ignition with compression engine.

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PROCEEDINGS OF 10IH INTERNATIONAL SYMPOSIUM ON FUSION OF SCIENCE AND TECHNOLOGY (ISFT-2024)
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ISFT ME - 170

ANALYSIS OF MECHANICAL PROPERTIES FOR EN31 STEEL SMAW V-BUTT JOINT WITH E7018 WELDING ELECTRODE

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ABSTRACT

At this present time, different types of steel are used for different purposes but in this article, EN31 high-strength alloy steel is used which is widely used in tools and dies. In this paper,an analysis of the mechanical properties of EN31 steel V-butt joint has been done which is prepared by the SMAW (Shielded Metal Arc Welding) process. The main purpose of this project is to determine the mechanical propertiesof the EN31steel joint which is prepared by SMAW and the joint of EN31 is filled with AWS E7018 Welding Electrode. In this research, 99.48 % increment in the hardness of the welded specimen in comparison to the base material and a 26.58 % reduction in the toughness of the material after performing welding on EN31 material. Now, come on ultimate tensile strength and elongation %age. There is a reduction in UTS and elongation %age of Welded specimen to base material. A 14.28% reduction is shown in the welded part and a 39.14% reduction in elongation percentage. It is found that the joint fabricated at a high heat input condition showsan excellent weld bead joint. This project mostly focuses on the analysis of the mechanical properties of EN31 Steel joints. This project includes the tensile strength of the joint, impact or toughness of the material joint and hardness of the heat-affected zone of the V-Butt Joint.

Keywords

SMAW welding, V-Butt joint, Welding electrode, Mechanical properties, Steel

INTRODUCTION

In this world, there are different types of steel and they have different properties for performing different tasks. Steel is the most popular material because it is used in a wide variety and steel has amazing properties. At the time of the heat treatment process on steel, steel shows different properties and due to this capability of steel, we can get desirable properties material. Steel is the most important material in all materials because everything around mostly wherever we use, is steel. For example, our utensilsare also made up of steel, that steel is stainless steel.

This material has a wide range of tremendous properties such as good welding characteristics, amazing ductility, good toughness and hardness and most importantly good corrosion-resisting capability. Steel is used in different sectors for different purposes [1]. There are a lot of things which are made from steel such as, tools, dies, machine compressors, shipparts, electric motor

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shafts, body, there are so many machines and their part and lots of other objects. Steel is everywhere;it is on roads, highways, bridges and railway stations, everywhere. Everyone cansee steel on the road because on roads, vehicles are there and all vehicle bodies and parts are made upof steel. There are different types of steel used to make vehicles.

In this world, low-carbon steel, medium-carbon steel, high-carbon steel, stainless steel, galvanized steel, ferritic stainless steel, austenitic stainless steel, martensite stainless steel mild steel and many more types of steel are present which are used to make vehicles, machine tools dies and machines also [2]. But in this project, we are dealing with high-carbon steel which is mostly used for tool and die purposes, and high-strength steel is required because the shock absorbing capacity of high-carbon steel is tremendous.

Now, little more discussion on the types of steel present in the market because without knowing about different types of steel we cannot further proceed towardsthis project. Broadly, Steel is classified into four types, out of these four types of steel all other sub-types of steel are made.

Types of steel

1. Carbon steel**2.**Alloy steel**3.**Tool steel**4.**Stainless steel

These steels which are listed above are the main types of steel; explaining these steels in short is required because there are lot of stuff on these steels which ultimately change their properties.

Carbon steel

Carbon steel looks like a matte colour or this can be something grey-like colour but this carbon steel has less corrosion-resistingproperties. In simple words, this material is weak in corrosion resistance. There are different types of carbon steel which are low carbon steel, medium carbon steel and high carbon steel. Carbon percentage in iron denotes these types of steel and other type of alloys are mixed in a small manner [3]. Carbon steel is used in strong places like vehicles, knivesand electricity wires and the automobile sector for making automobile parts and many more. Some important points are-

- Low carbon steel contains 0% to 0.3% carbon content.
- Medium carbon steel contains 0.3% to 0.8% carbon.
- High carbon steel contains 0.8 to 2.1% carbon
- If we go above 2.1% carbon it becomes Cast Iron
- Cast iron contains 2.15 to 6.67% carbon.

The percentage of carbon mixed in iron and then mixing of carbon and iron make steel for our use. Carbon percentage is the most important factor for carbon steel and for this project,high-carbon steel is used [4].The name of the material being used in our project is EN31 steel. EN31 is a high-carbon alloy steel.

In this project, high carbon steel alloy materialwas used which is EN31 steel. There are a lot of grades in carbon steel but selected EN31 for this work.

Now, come on to the welding process, there are a lot of welding processes which can be used for welding for different purposes.

Types of Welding Processes

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- Spot welding, Projection welding, shielded metal arc welding, gas metal arc welding, Gas tungsten arc welding, Flux-cored arc welding, Submerged arc welding, Oxy-Acetylene gas welding,Carbon dioxide gas welding, Hydrogen gas welding, Thermit welding, Soldering and Brazing welding, etc

So, from the above list of welding processes, these welding process comes under, resistance welding, arc welding, gas welding, etc. But out of these welding processes we select the shielded Metal Arc welding (**SMAW**) process. The SMAW process is also known as Manual Metal Arc Welding and in most places, people say Stick welding process [5]. Now, little more discussion on Shielded metal arc welding because this is the main process of this project. In this project Shielded metal arc welding processis used and it can be called SMAW with a consumable electrode.

Shielded metal arc welding (SMAW)

Shielded Metal Arc Welding is a process of joining two or dis-similar metals with the help of filler material by an electric arc. SMAW is a type of electric arc welding process. In SMAW, Consumable electrodes are used, without consumable electrodes this process cannot be possible. Before understanding this welding process, first, we know what equipment is used in this welding process.

Equipment of SMAW Process

- Electrode Holder, Welding cables, Welding machine, Welding electrode.

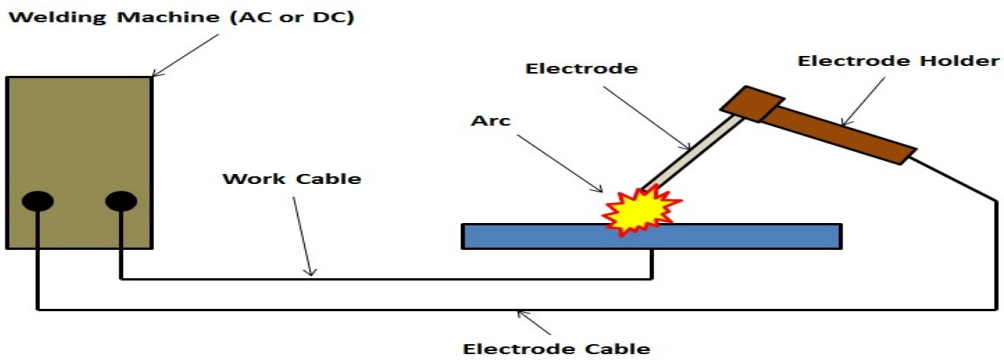


Figure 1. SMAW Process

Now, it is important to understand how the equipment of the SMAW process is setup. There are two terminals in the welding machine one terminal is connected to the base metal and another one is connected to electrode holder. The electrode is fitted in electrode holder, and when the electrode touches the base metal, then electric circuit is complete [6]. After that an arc is generated and current gets started flowing into the circuit and we can perform welding.

In SMAW process there are three polarities which are DCEP, DCEN, AC polarity. These polarities are used for different purposes just like if we want deep penetration, then we choose DCEP polarity if we want low penetration in base metal, choose DCEN polarity and medium penetration in material then AC polarity is chosen.

In this project, a consumable electrode and the name of that electrode is E7018. SMAW process cannot be performed without consumable electrodes but there are two types of electrodes

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consumable and non-consumable electrode.

Now, this is all about SMAW process, for completing this project, it is important to understand mechanical properties.

Mechanical properties

Mechanical properties are those properties, at which material strength is defined. Mechanical properties are the strength definition for any material [7]. With the help of these properties, the material shows different behaviours such as high shock absorbing capacity, capacity to resist scratch or indentation, heat resistance capacity, etc. Some mechanical properties are given below.

- Hardness, Toughness, Brittleness, Ductility, Tensile strength, Compressive strength, Shear strength, Torsional strength.

These are the properties of metal. In this project, only analyse the hardness of welding joint, toughness, and tensile strength of the welding joint material. Analysis of these three mechanical properties will be performed in this experiment.

Existing work

Existing work is that work which is running or pre-existed from other sources. In this, already performed work is coming. Now, there is a talk about some existing work on the EN31 material and which type of research is performed on this material.

- Analysis of Mechanical properties of En31 V-Butt joint with ER-308L Filler material using TIG welding.
- Microstructure analysis of EN31 joint with ER-309 filler material using TIG welding
- Effect of SMAW on EN31 by varying welding parameters.
- Effect of welding processes on EN31 steel joint.

These types of existing work are run on En31 material which give great knowledge about the mechanical properties of EN31 and also tells how microstructure change with welding.

Proposed work

After discussing about existing work, now come on to the proposed work, what work will be performed in this experiment.

- After looking at pre-existing work on EN31 material,it is found that there is no more research available on EN31 steel with E7018 electrode.
- There is no information available for the mechanical properties of EN31 steel with E7018 filler material.
- So, in this project it is decided to get more research on EN31 steel with E7018 electrode using SMAW electrode**.**
- Finally, our project, analysis of mechanical properties for EN31 steel SMAW V-Butt joint with E7018 welding electrode.

MATERIALS AND EQUIPMENT'S

In this chapter, which material is selected for performing this project and which equipment is

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used during this experiment. Without discussing the material, no one is further proceeding with this project because before performing this project, to know about the material of this thesis [8]. After knowing the material properties, for taking an idea of their mechanical properties and selected perfect capacity of equipment for testing the material properties and analysing them properly.

Materials

Selection of base metal for welding

For this project carbon steel alloy is selected and the name of that steel is EN31. In this material "EN" denotes" European Norms" and "31" denotes the series number of carbon percentage.

EN31 steel is a high-carbon steel alloy. Carbon %age in this material is 0.9%, which means it is a high-carbon steel material because in carbon %age of high-carbonsteel is 0.8% to 2.1%.

En31 material is widely used in tool and Die purposes and this material is also used in hydraulic crane tool digging. This tool has a better wear resistance capacity and heat-absorbing capacity.

En31 material is mainly based on carbon percentage because carbon %age matters, and how much strength is present in the material [9].

Carbon is the most important factor in steel. The reason for choosing steel is because it shows different behaviours of mechanical properties when a heat treatment process is applied with this material. When welding takes place on steel,different mechanical properties and microstructure of the welding portion can be seen.

Chemical composition of EN31 Steel

This table contains various types of material because EN31 material is not made up of single material, it is a mixture of various metals.

Table 1. Chemical Composition of En31 Steel

Material	Percentage (%)
C	0.90-1.20
Mn	0.30-0.75
Si	0.10-0.35
S max	0.05
P max	0.05
Cr	1-1.6

Selection of welding electrode

As per information, there are various types of electrodes used for welding purposes but every electrode has different strength according to their properties. Welding electrodes such as E6013, E6014, E6016, E7024, E7016 and E7018 are used for joint purposes but in this project, **E7018**welding electrode is used[10].

E7018 welding electrode is coated with low iron powder and it is mainly used for high metal deposition rate. For high deposition rate, DCEP polarity can be used and AC polarity can also be

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used. Because DCEP polarity also called DCRP (direct current reverse polarity) [11]. DCRP is another name for this polarity.

Electrode designation can be discussed here to understand these numbers which are used in E7018 welding electrode. What is the meaning of these numbers in welding electrode?

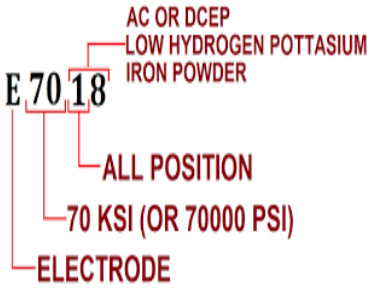


Figure 2. Designation of E7018 Welding Electrode

(Source-https://www.weldingandndt.com/welding-electrodes-understanding-the-electrode-symbols/)

Chemical composition of E7018 Electrode

Chemical composition of E7018 electrode is shown in the given table. E7018 electrode internal material is the composition of different material but the main material is carbon %age [12].

Table 2. Chemical Composition of E7018 Electrode

Materials	PERCENTAGE (%)
C	0.07
Mn	0.86
Si	0.60
P	0.015
Ni	0.02
S	0.011
Cr	0.03
Mo	0.01
V	0.01

This is all about the material used in this project and used only these two materials one is EN31 steel and another one is E7018 electrode. Now, move on to which equipment is used in this experiment for performing the task. For checking mechanical properties and microstructure analysis which equipment or machines are needed?

Selection of equipment and machines

The selection of machines and equipment are important for this experiment. At the time of welding process, which machine is required, and after welding, which equipment is required for cutting or preparing the job for testing [13]. When the job isprepared, which machines are required for mechanical properties. In this section, we will cover this thing and purpose of talking about this topic is only to become familiar with testing machines and equipment. because

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without getting details about machines,it is impossibleto further proceed.
For preparing welding joint, for preparing jobs, for testing mechanical properties, and for analysing the microstructure, some machines and equipment are required which are listed below. There is a list of main equipment, without this equipment it is impossible to perform this experiment.

1. Automatic Power Hacksaw Machine
2. SMAW Welding Machine
3. Grinding machine
4. Digital Microscope
5. Vickers Hardness Machine
6. Impact Testing Machine
7. Universal Testing Machine (UTM)

EXPERIMENTAL METHODOLOGY

In this chapter, we conclude all processes whatever is applied on the material, from the pre-testing of material to the last testing of material [14]. There is a division of this experimental process into different steps or sub-chapters.

Cutting of EN31 steel for the experiment

- First of all, buy an En31 steel plate and the size of that plate is large, for the experiment purpose requirement of small size plates. So, with the help of **Power Hacksaw**, the material is cut into small pieces.
- The size of a single piece is **100mm×75mm×7mm**. We prepare four pieces. Two pieces for welding joint, one piece for pre-testing of material and the last piece for rough practice of welding on EN31 steel by E7018 electrode.

Testing of EN31 workpiece

- After cutting and preparing a specific size of material, performa hardness test on the En31 material because it is compulsory to know the hardness of the material before applying welding because after welding properties of the material changed.
- For testing the hardness of the sample, usethe Vickers hardness testing machine.
- Material at 30Kgf and after this, Vickers hardness number is calculated by formula. Process of finding Vickers harness number in next sub-chapter of mechanical properties testing.

Table 3. VHN, Toughness, UTS, Elongation % age of Base metal EN31

Base metal	(VHN)	Toughness(J)	UTS (MPa)	Elongation %
EN31 Steel	143	79	784	23.5

Preparing V-Groove for Welding

- When testing of EN31 is completed after that, there is a turn of making v-groove on the plates of material

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- For preparing V-butt joint, we have to prepare V-groove between the jointing line.
- A 90^{o} angle V-groove is prepared between the joining line
- 45^{o} angle is created on the edge of one piece with the help of 3 cut file and bench-vise.
- When the 45^{o} angle is ready on both pieces, after this, keep both pieces together to seea 90-degree angle.
- When the angle is prepared, clean the surface of the material.For preparing this V-groove, a 3-cut file and bench vice is used. Without this equipment, it is impossible to develop this groove. Now, the image of that grove is given below.



(a) (b)

Figure 3.(a), (b) 90^{o} V-groove on En31

V-Butt Joint by Shielded Metal Arc Welding Process (SMAW)

- When the V-groove is prepared, then we can go for the welding process.
- The SMAW process is used in this experiment for preparing the V-butt joint.
- Before preparing V-Butt joint in the grove, first perform spot weld on the backside of the workpiece.
- Tack weld is performed on the material, ifnotperformed this tack weld and direct apply welding on the V-butt groove, the material can be bent during welding.
- To avoid this angular distortion, use tack weld on the backside of the workpiece.



(a) (b)

Figure 4. (a) Tack weld on the backside of En31 workpiece and (b) front view

- After making a spot or tack weld on the workpiece, start welding on the V-Butt groove.
- V-Butt groove is not filled within one pass of welding. One pass means itstarts welding from the top point of the workpiece and ends up at the bottom edge.

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- V-Butt joint is prepared in 4 passes of welding. After 4 passes of weld, the joint is ready.
- 4 passes of welding at the V-Butt join can be shown in the figure.



(a) (b)



(c) (d)

Figure 5. (a) 1st Pass Weld, (b) 2nd Pass weld,(c) 3rd Pass Weld, (d) 4th Pass Weld

- V-Butt joint is prepared after 4 passes.
- Welding of En31 is complete.
- Welding Parameters are given below for this V-butt joint
- SMAW process welding machine sets on

Current- **118 amp**
Open circuit voltage- **100 V**
Closed circuit voltage- **25-35 V**
Polarity- **AC**

- Welding joint Pass takes time

1st pass **28 sec**
2nd pass **32 sec**
3rd pass **34 sec**
4th pass **48 sec**

- Welding speed (mm/sec), we know (speed = distance/time) and we have a 100 mm length of workpiece.

1st pass **3.57 mm/sec**

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2nd pass **3.125 mm/sec**
3rd pass **2.94 mm/sec**
4th pass **2.08 mm/sec**

- Final image of V-Butt joint.



Figure 6. V-Butt Joint on En31 with E7018 Electrode using SMAW

Jobs for Testing Mechanical Properties

- After preparing the V-Butt joint on EN31 steel, now there is a turn for job preparation.
- Jobs are prepared for mechanical properties and microstructure analysis.
- These Jobs are prepared from welded workpieces for testing tensile strength on UTM, toughness from the Charpy test, and hardness by the Vickers testing machine. These all are mechanical properties testing
- All jobs are prepared with the help of an Automatic Power Hacksaw machine and heavy Grinding Machine.
- Dimensions of these jobs are kept in mind according to standard specimens tested on UTM, Impact testing machine and Vickers Hardness Tester.
- When jobs are fully prepared, they look like-



Figure 7. Actual Jobs for Testing

- These above jobs are further forwarded for tensile, hardness, and toughness.

Vickers Hardness Testing

- Now, the job is ready for the Vickers Hardness test.

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- Hardness Test performs on the Vickers hardness testing Machine.
- The range of load for testing the hardness of material is from 10Kgf to 50Kgf.
- In the Vickers hardness machine, a square pyramid diamond indenter is used to check the hardness of the material.
- The angle of the square pyramid indenter is 136^{o}.
- For finding Vickers hardness Number (VHN), a formula is used

  $VHN = 1.854 \times (F/D^2)$

  Where, F = Load applied in Kgf

  $D = (D_1 + D_2)/2$ (D is in mm),

  (D_1 = Main scale + Gauge scale) and same for D_2.

  Where D_1 and D_2 are diagonal of square pyramid indentation on the workpiece.
  - Vickers hardness testing machine is given below with the workpiece.



Figure 8. Vickers hardness testing machine with job specimen

- 30Kgf load is applied tothe material at the centre of the joint
- After this, the specimen is tested at 10 more points which are located at a distance of 5mm.
- 5 points on the left side and 5 points on the right side from the centre of the v-butt joint
- After that, note reading of D1 and D2.

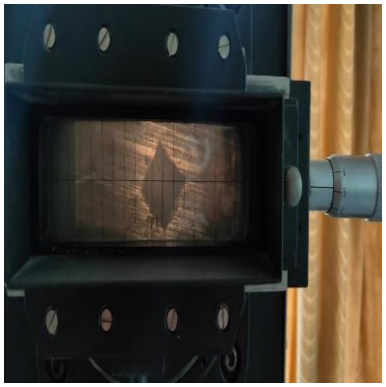


Figure 9. Impression of Square pyramid diamond indenter

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- For Readings, prepare a table. In this table, what is the length of the diagonal at different points and VHN.
- Before this, notify the centre point and the other 10 points.

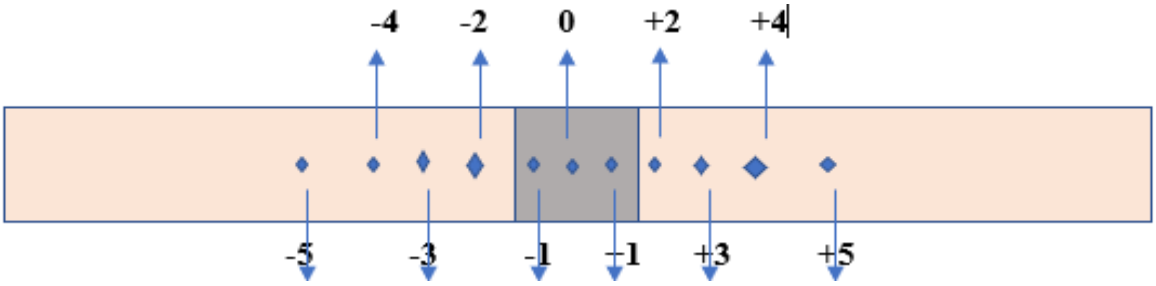


Figure 10. Hardness testing point on Specimen

- Now, see 10 pointsinthe above figure, we tested the harness at these points and the distance between each point is 5mm.
- Now, understand the reading and VHN with the help of the table.

Table 4 Vickers hardness number (VHN)

Points / Reading	D_1 mm	D_2 mm	$(D_1 + D_2)/2$ mm	V.H.N.
+5	0.41	0.42	0.415	322.95
+4	0.42	0.41	0.415	322.95
+3	0.43	0.44	0.435	293.93
+2	0.44	0.41	0.425	307.93
+1	0.54	0.51	0.525	201.79
0	0.5	0.51	0.505	218.09
-1	0.45	0.43	0.440	287.29
-2	0.45	0.43	0.440	287.29
-3	0.43	0.44	0.435	293.93
-4	0.43	0.44	0.435	293.93
-5	0.42	0.43	0.425	307.93

- With the help of the Vickers hardness tester, VHN is calculated.
- **VHN** varies at different points.

Charpy Test of Welded Job

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- Charpy test is performed on the impact testing machine. The size of the specimen is already mentioned in the job preparation sub-chapter (5.5).
- Image of the Charpy specimen is given below and there is a 45-degree notch in the middle of the weld portion.



Figure11. Charpy test specimen

- Charpy test is performed using this above specimen.
- First, keep the specimen in vise at a simply supported position because the Charpy test is performed when the specimen position is simply supported.

Table 5. Charpy test result

Material	Electrode	Toughness (J)
EN31 steel	E7018	58

- Impact toughness is 58 J. It means the capacity to store the potential energy of the specimen up to the fracture point is 58 joules.
- This test is performed on an impact testing machine which is given below.



Figure 12. Specimen in Vise with Impact Machine

Tensile strength on UTM (Universal Testing Machine)

- Tensile test is performed on a Universal Testing Machine. UTM is used for various tests such as compression, tension test, etc.
- But in this project onlya tension test is performed and specimen dimensions are given in chapter 5.5.

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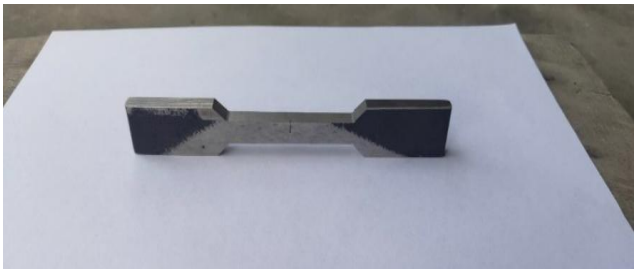


Figure 13. Tension Test Specimen

- With this specimen, performed tension test on UTM.
- Results of the Ultimate tensile strength (UTS) test is shown in the table.

Table 6. Result of tension Test

Material	Electrode	Load at Yield (KN)	Yield Strength (MPa)	UTS (MPa)
EN31	E7018	42	508	672

- Result in percentage of Elongation for EN31 steel specimen.

Table. 7. Result of elongation

Material	Electrode	Original length (mm)	Final length (mm)	% age Elongation
EN31	E7018	60	68.58	14.3

- The image of the V-butt joint cannot be seen by eyes, for understanding the detail of the v-butt joint, the image of weld bead cross-section should be there.

With this, our experimental methodology ends and explains the methodology in a very smooth flow step by step because without step it is impossible to understand this experimental project. Now, move on next chapter which is related to results and discussion.

CONCLUSION

This project prepared a V-Butt joint with a 90-degree angle using the SMAW welding process. After preparing the V-Butt joint, analysis of Mechanical properties and microstructure condition of EN31 steel is completed. This joint is prepared using E7018 Electrode.After finding the mechanical properties of welded joint, there is a reduction in toughness and elongation % age of joint in comparison to base metal, but the hardness of welded joint is increased in comparison to base metal.There is a 99.48 % increment in the hardness of the welded specimen in comparison to the base material and a 26.58 % reduction in the toughness of the material after performing welding on EN31 material. Now, come on ultimate tensile strength and elongation %age. There is a reduction in UTS and elongation %age of Welded specimen to base material. A 14.28% reduction is shown in the welded part and a 39.14% reduction in elongation percentage. So, from this experimental project, we find some new behaviour of EN31 with E7018 using SMAW. We have the latest knowledge about the mechanical properties of EN31 steel with E7018 electrodes. This has become helpful for welding of breakage tools of hydraulic cranes and now this project come to an end with this kind of helpful information and we achieved all objectives.

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WASTE TYRE RUBBER-THERMOPLASTIC COMPOSITE MATERIAL FOR FDM 3D PRINTING- A REVIEW

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ABSTRACT

In this world, a lot of pollution is created by waste tyres which are used in vehicles and this pollution is very dangerous for human beings because when waste tyres are accumulated for a long time then this creates a lot of harmful gases, mosquitoes and different types of diseases which is intolerable for the environment as well as for humans. Different types of waste tyremanagementare being worked on to decrease this pollution but that is not enough. So, to decrease this pollution, a new approach is here by using waste tyre rubber with thermoplastic polymers for Fused deposition modelling (FDM). FDM is a process of 3D printing. 3D printing is a manufacturing process. This review article is all about how waste tyre rubber can be used for additive manufacturing. In this paper, step by step procedure is discussed for developing waste tyre rubber-based thermoplastic composite material which can be used for 3D printing. For developing 3D printed material, melt flow index (MFI) and thermal scanning are the major part of making a composite material. After this, a filament wire is prepared with the help of a double extruder then this filament can be used in an FDM printer. The next step is all about the testing of printed composite material. Mechanical properties and microstructure analysis type of testing are discussed in this article.

Keywords
Waste tyre rubbers, Thermoplastics,Fused Deposition Modeling (FDM), 3D printing, Polymer composites.

INTRODUCTION

Additive manufacturing (AM) is the process of creating three-dimensional (3D) objects from computer-aided design (CAD). 3D printing is another synonym for additive manufacturing. 3D printing is a technique of developing 3D objects with a process of layerdeposition of material with the help of 3D printers[1]. 3D printing process candevelop complex shape products easily but in conventional manufacturing processes, that is not an easy task.

In 3D printing, the material is printed step by step with computer controls. Thereare a lot of 3D printing technologies available in the market but the process of printing the product is

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considered within six steps. These steps will be understood by a block diagram of the 3D printing process. This process includes some steps like a 3D model, STL file, slicing, G-code, 3D printer and 3D product. In the first step, a 3D model of the object is prepared by CAD software and a 3D image scanner. After this, the 3D model is converted into an STL file, and then the slicing of the STL file is performed by slicing software. This software also converts the slicing of an object into G-code. G-code is a type of language which is understood by machines (3Dprinters). When the G-code file comes into printer control, the printing of the product begins. So, these steps can be seen inthe block diagram of the 3D printing process which is given below.

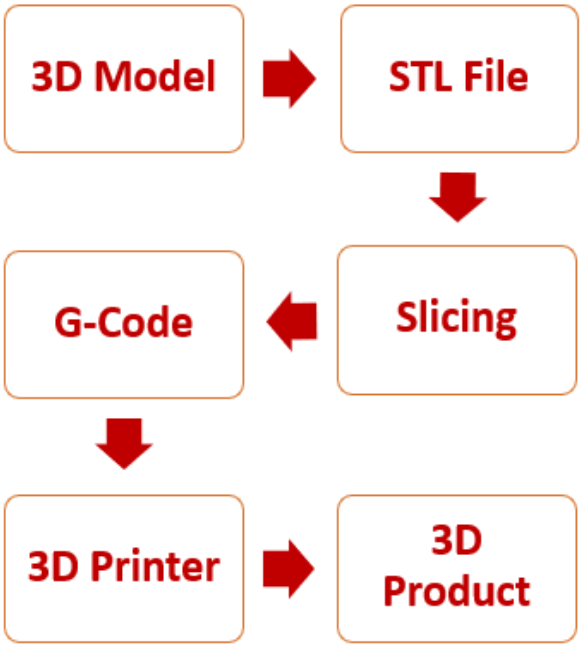


Figure 1- 3D printing process

FDM- Fused Deposition Modeling

3D printing was introduced around the 1980s for creating prototypes, but these days this is not only limited to prototypes, this technology is used in many sectors such as automobiles, education, sports, production, and many more. Today, a lot of technologies are presented in the market for 3D printing such as stereolithography, fused deposition modelling, selective laser sintering, lamination, and direct metal sintering but out of these technologies, the fused deposition modelling process is very popular among these 3D printing technologies.

FDM is suitable forthe 3D printing of polymers. FDM is widely used for plastic products. There are a lot of thermoplastic polymer productsthat are used in daily life and these plastics are printed through an FDM 3D printer. FDM printer is a setup of filament, filament spool, feeder, heater, nozzle, printing bed, printing structure, etc. According to Saty Dev and Rajeev Srivastava,FDM

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is a process of layer deposition from a nozzle extruder[2]. In this process, a filament is fed through a filament spool and this filament is fed into a nozzle. This filament is moved into the extruder by the feeder mechanism. The feeder mechanism consists of a gear arrangement. When filament comes intothe extruder, it becomes semi-melt form with the help of heating elements, and then melted material comes out through the nozzle and is deposited layer-by-layer on the printing bed[2]. This FDM process is very easy to use, which is why it is so popular in the 3D printing industry.

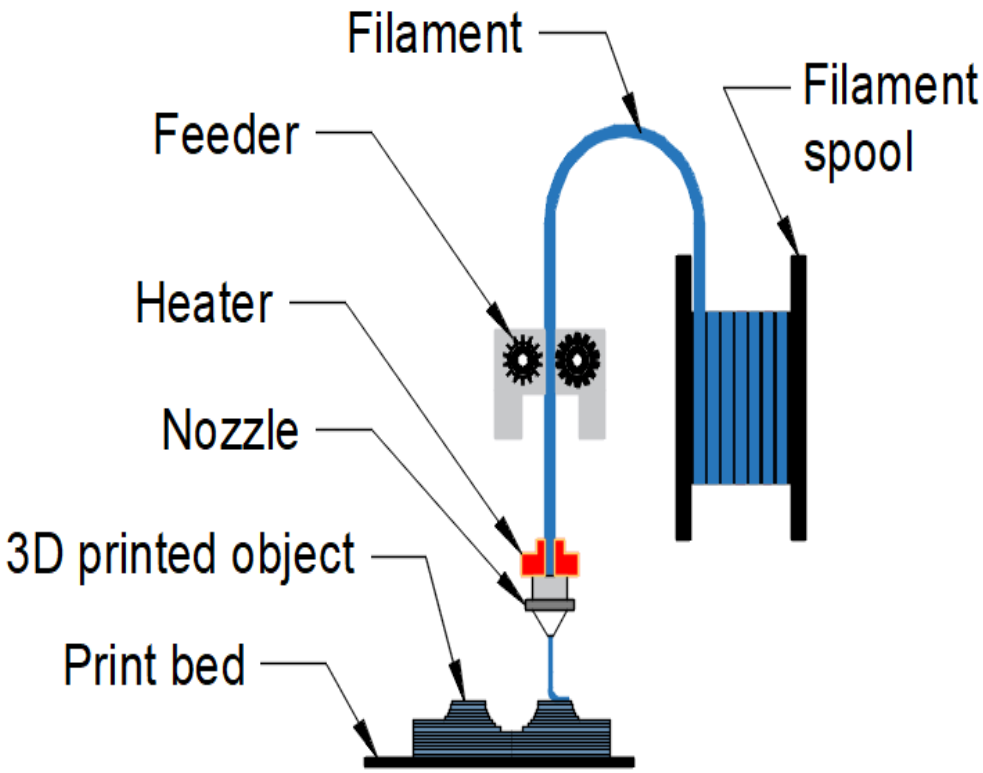


Figure 2- FDM Process

Types of material used in FDM

Different types of polymers are used in FDM, but some popular materials are widely spread for the FDM process. FDM can be easily used for thermoplastic, thermosetting, and composite materials.

- Polylactic Acid (PLA)
- Acrylonitrile Butadiene Styrene (ABS)
- Poly-ether-ether-ketone (PEEK)
- Polyurethanes (PU)
- Thermoplastic Elastomers (TPE)
- Composite polymers

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These materials are commonly usedin 3D printing, but these days there is more demand for new materials.

Presently, waste tyres are increasing day by day and this becoming a serious problem for the environment. According to waste management industries, 1.3 billion waste tyres are produced yearly in this globe world worldwide and India is in 6th place for producing waste tyres in this world. These waste tyres create pollution in the environment which is toxic for human beings. There are a lot of processes going on to reduce these waste tyres.



Figure 3- Waste Tyre

The first use of this waste tyre rubber as a binding agent in cement was performed by David Fedroff,Shuaib Ahmad, and Banu Zeynep Savasin 1996[3]. In this research,the author mixed the waste tyre rubber in cement to increase mechanical properties. Cementhardness was increased by this research.

After this, in 1998 Christopher M.B. Lehmann et al. [4] used waste tyre rubber for reducing air pollution. Waste tyre rubber was used as a carbon-absorbing agent.This author performed an experimental investigation for improving air quality by using waste tyre rubber.

After that, a lot of researchwas performed on increasing cement strength by using waste tyre rubber, but around 2006, Xin-Xing Zhang,Can-Hui Lu, and Mei Liang[5]developed a composite material by ground tyre rubber with waste fibre by milling method. In this research, Groundtyre rubber (GTR) was used as a host matrix and waste rubber fibres as reinforcement.

In 2015, a review was provided on wastetyre rubber with polymers by S. Ramarad et al. [6]. In this review, waste tyre rubber-based polymer evolution, mechanical properties, and preparation of GTR from waste tyresare given. GTR is prepared by the devulcanization process for blending in polymers because the rubber of waste tyre is a vulcanized rubber and vulcanized form cannot be blended.

There is a need fora compatibilizer agent for preparing the GTR-based composite polymer. The

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bonding of these composite polymers is less but from a compatibilizer agent, this can be strong. Different processes are used for making strong and adhesive bonds[7].

In 2021, Fouad Laoutid et al. produced a composite material for 3D printing. This author used GTR as filler in thermoplastic polymers and these thermoplastics were ABS and TPO.Fouad Laoutid et al. [8] compared the mechanical properties of composite materials with a host polymer matrix and in that comparison, composite materials have better properties.

Alot of research was performed on GTR-based composites but when additive manufacturing technology came, a lot of composite materials were developed for providing better mechanical properties to the product. 3D printing enables the door todevelop new composite materials because this technology can easily print complex shapes and composite materials there is so much demand for composite material in the 3D printing industry.

Due to this requirement, research is going in the direction of composite materials, but this research will be focused on waste tyre rubber-based composite polymer because in this world, there are a lot of vehicles and these vehicles produce more waste tyres. As waste tyre disposal is a great problem, this research may help in mitigating this issue, in tune withrepair,recycling, and reusing.Waste tyre rubber is also used in cement and new composite polymers. The evidence of using waste tyre rubber can be seen in many investigation and review papers.

So, by using the waste tyre rubber material as a reinforcement in polymer, thisresearch will suggest a new composite material for 3D printing. This will be the good for 3D printing industry which willbe focused on providingbettermechanical properties of the material. Due to this, social work will also happen by reducing some amount of waste.

LITERATURE REVIEW

Tuan D. Ngo, Alireza Kashani, 2018

This paper focused on general information about additive manufacturing (AM). This paper is all about types of additive manufacturing, what materials are used in 3D printing, what challenges are there in additive manufacturing and what are the applications of additive manufacturing.

AM have many advantages over conventional manufacturing such as easy-to-develop complex shapes and products can be produced on demand, there is no need for stock inventories. AM leads to a decrease in the wastage of material at the time of printing product because AM is the process of layer deposition on the previous layer and the product is prepared by this deposition process rather than the subtraction method. The subtraction method is a part of conventional manufacturing, in this manufacturing, the product is prepared with the help of subtraction material from a large piece of material. So, due to this activity, AM has the advantage of waste minimisation over conventional manufacturing.

In this paper, AM is used in the automobile industry, biomedical industry, and construction industry. AM enables the printing of thermoplastics, metals, composite materials, alloys, ceramic materials and much more. For printing these materials, different type of processes is used such as FDM, SLA SLS, etc. Some challenges are also faced in AM like the limitation of complex

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design in the computer, void formation on the printed part, and strength of the printed product. Overall, this paper concludes all the basic and moderate information about additive manufacturing[9].

JiriSafka, Ackermann Michal, 2016

In this article, the author prepared a polymer composite material. This polymer composite material is a combination of natural fibres and thermoplastic material. The composite material was converted into a filament form. After this conversion, the filament was fed into an FDM printer. After this, a product was printed from FDM. The tensile strength of the printed part was tested. The tensile strength of 3D printed composite material was compared with the same composite material but this composite material was prepared by injection moulding.

There was a comparison between the same composite material but this composite material product was prepared by two different methods, one is fused deposition modelling and another injection moulding process. Injection moulding is related to the conventional manufacturing method and FDM is the 3D printing method. So, there was a comparison between modern and conventional manufacturing but the material of that product is a natural fibre-based thermoplastic composite material[10].

Carl G. Schirmeistera, Timo Heesa, 2019

In this article, high-density polyethylene (HDPE) material is printed by fused filament fabrication (FFF). HDPE is a part of polyolefin thermoplastics. HDPE is widely used in this world on a large scale due to its recycling, eco-friendly and sustainable nature. 3D printing of HDPE from FFF also called fused deposition modeling (FDM) of HDPE. However,more problems have been created during the 3D printing of HDPE. The problem of shrinkage of the printed part, void formation and weak bonds have been produced between the finished product.

However, in this article, these problems have been solved by varying process parameters of printers such as printer speed,thickness of a layer, nozzle diameter, base plate temperature, chamber temperature, and extrusion rate.

By varying these parameters, tensile strength, Young's modulus, and surface finish are also improved. With the help of the extrusion rate, the void formation problem was also solved. In this article, there is a comparison of HDPE products which are developed by injection moulding and the FDM process. After comparison, HDPE shows almost similar mechanical properties. In this article, mechanical properties and microstructure images were captured which shows excellent fusion of HDPE material[11].

Marina León-Calero, Sara Catherine Reyburn Valés, 2021

In this article, an experimental investigation of 3D printing with thermoplastic elastomers (TPE) was observed. With the help of chemical composition in TPE printing products, a change in the

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damping capacity and energy absorbing capacity was observed. Additive manufacturing is the amazing technology to produce complex shape structures and reduce manufacturing time when a product is immediately required. TPEs are commonly used in 3D printing because of their great energy-absorbing capacity, and damping capacity. According to the authors of this paper, there is more investigation was performed to optimize the thermoplastic elastomer filaments, tensile strength, and other mechanical properties but an extra experiment also performed with thermoplastic polyurethanes (TPU).

TPU filaments were investigated with a differential scanning calorimeter (DSC). Tensile strength and compression strength were also improved with the help of printing process parameters. For TPU material, different infill densities and different infill patterns were used to improve mechanical properties. Different compression strength was observed with different infill density. Optimal specific energy absorption (SEA) was observed with a honeycomb infill structure at 50% infill density [12].

Salman Pervaiz, Taimur Ali Qureshi, 2021

In this article, a fibre-based reinforced thermoplastic composite was printed through fused deposition modeling (FDM). When two or more types of materials are used to develop a material is called composite materials. Composite materials are developed for enhancing mechanical properties. So, to enhance mechanical properties in this research, researchers used fibre reinforcement in thermoplastics. Thermoplastic and composite materials can be printed on FDM with some changes in printer and material.

Fibre-reinforcement polymers (FRP) are very famous materials in the defence industry, sports, automobiles, and biomedical fields. FRP have high strength and less weight material. Due to additive manufacturing, FRP products can easily be supplied in these industries.

The FDM process enables the manufacturing of FRP products with complex shapes which is not possible with conventional manufacturing methods. The author faced some problems and limitations in developing FRP material for 3D printing. This paper is very helpful for those who want to work on 3D-printed FRP composite material[13].

S. Ramarad, C.T. Ratnam, 2015

This paper gives a review of scraptyre rubber (STR) in polymers and,the evolution of scraptyre rubber-based composite materials. This paper shows the progress of scraptyre rubber-based polymer. The polymer can be thermoplastic or thermosetting. Scraptyre rubber can be mixed in polymers from different methods. Thistyre rubber cannot be mixed directly with polymers because the first step is to convert scraptyre rubber into ground tyre rubber (GTR). After that, the GTR size should be decided, some other binding agents are also required for preparing WTR-based polymeric material. Some types of binding agents are suggested for this.

Mechanical properties of WTR-based polymeric material can vary with the WTR particle size. WTR blends with thermoplastic suffer a problem of low tensile strength but WTR-based

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polymers show a good performance in the shock absorbing fields. There is a way to reduce the wastage of tyres in this world with polymers. Polymers are widely used in every field. This paper also shows the lack of studies on the thermal behaviour and microstructure studies of WTR-based polymer composites [6].

Alkadi, Faez,Jeongwoo Lee,2019

In this research article, GTR is prepared from scrap tyre rubber and this GTR is mixed as a filler in a polymer matrix. FLX930 polymer was used as a host matrix. After mixing these materials, some blending agents were also added to this composite. A thick type solution was prepared, and this solution was filled into a syringe (nozzle).

Material is extruded from the syringe nozzle with the help of a pressure controller. In this 3D printer, an extruder is replaced by a syringe nozzle and there is no filament process. In this printer, the material was filled in a syringe nozzle and this nozzle was connected to a pressure controller tube. After printing this composite, a tensile test was performed. The tensile strength of this printed part has been compared with the moulded part of this same material. The result of this research, GTR can be used in polymers as an ink if rubber properties are required in polymers[14].

Balázs Heller1, Lilla Simon-Stőger, 2022

In this paper, the author mixed three types of material. Ground tyre rubber, waste of HDPE, and ABS were mixed by the process of milling roller. These three materials were mixed with two rollers. But, after mixing these materials, there was an addition of two bonding agents which are maleic anhydride grafted polypropylene and olefin maleic anhydride copolymer. After mixing all these materials, a Scanning electron microscopy test was performed for microstructure bonding. This experiment is only for checking the ability of GTR to makebonds with ABS and the wastage of HDPE. However, this experiment shows GTR amount can be increased for mixing[15].

Maoyong He, Kai Gu, Yulong Wang, 2021

In this article, the author developed a ground tyre rubber-based composite material with polyurethane elastomers. The author'sperspectivewas waste tyres with polyurethanes (PU) canproduce highly performance thermoset polymer material.

In this research, composite material is prepared with 3.44% GTR mixed with polyurethanes. Due to this proportion, the tensile strength of newly developed composite material is increased by approximately 166% approximately to pure polyurethane. The dynamic heat generation index of this developed composite material is 0.97 which is lower than polyurethane. The dynamic heat generation index of PU is 1.67 and this dynamic heat generation index is at 100^{o}C. After that, X-ray photoelectron spectroscopy was performed, and the results were GTR particles distributed uniformly with a network pattern. This research provides a low-cost high-performance GTR-thermoset polyurethane composite material [16].

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Sachini Wickramasingh, Truong and Phuong Tran, 2020

According to this paper, Fused Deposition modeling (FDM) is suitable for thermoplastic materials. For printing thermoplastic material, FDM is the most famous process among all additive manufacturing processes. This paper tries to find out the defects developed at the time of printing on fibre-reinforced composite (FRC) and suggests some treatments to decrease these defects. Due to this suggestion mechanical properties of FRC increased. FRC is the fibre-reinforced polymer matrix which is printable through the FDM process of 3D printing. The main defects in printing FRC material are void formation, poor bonding, and poor surface roughness but these defects can be removed by varying process parameters such as infill density, printing speed, bed temperature, etc. This paper helps us understand the defects generated in 3D printing [17].

Narinder Singh, Rupinder Singh, I.P.S. Ahuja, 2018

In this research, a composite material wasdeveloped for the FDM setup. The composite material is a combination of waste high-density polyethylene (HDPE), silicon carbide, and aluminium oxide. In this research, waste HDPE was collected from different industries. After the collection of these materials, the material flow index (MFI), temperature for printing by DSC, and ceramic bonding properties with HDPE were tested. In the next step,the composite material was prepared with the help of a twin-screw extruder (TSE) for proper mixing and then, a uniform-diameter filament was prepared. This filament is prepared for FDM setup. This research highlights the process of developing filament for FDM which is useful for research work [18].

Piotr Olesik, Mateusz Kozioł, Daria Konik, 2019

This paper created research on the damaged wind-screen glass as reinforcement with low-density polyethylene (LDPE). Powder of damaged wind-screen glass was prepared by some grinding method. The range of powder was 90 µm to 160 µm. This power of damaged glass was mixed with LDPE. So, due to this activity, a new composite was developed. This composite was converted into a filament with a 1.45 mm diameter for 3D printing. An FDM process was used to print this composite.

In this research, the author used 250^{o} C nozzle temperature and 90^{o} C bed temperature for this composite material. One problem has arose with this printing was the bending of filament at the time of printing. But, when the speed of printing became less than 1 mm/s, then this problem was solved by speed variation. Samples of the composite material were printed by FDM. There was very little deformation of the composite material. In this paper, the author mentioned a point that LDPE stiffness was not more affected if the damaged glass powder amount should be a minimum of 30%[19].

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2. Conclusions from the Literature Review

From the review ofthe above literature, certain conclusions are made as follows:

- It can be understood that additive manufacturing develops a product with a process of layer-by-layer deposition but conventional manufacturing follows the process of subtracting material. So, the product developed by the process of subtraction of material is called subtracting manufacturing but in AM, the material is added rather than subtracted.
- In 3D printing, there is no need to maintain stock inventories because the product can be produced on demand by a 3D printer.
- Different types of printing processes are available for different types of material. Now, it become easy to select the type of printer based on material which is only possible by the above Literature Review of 3D printing.
- For polymeric products, the Fused Deposition Modeling (FDM) printer is available. FDM printer uses a wide variety of polymers such as different types of thermoplastic polymers. For example, PLA, ABS, PEEK, and elastomers are used in FDM printers and different types of thermoplastic composites can be used in this process.
- Composite polymers used in 3D printing have high strength, lightweight, and better wear-resistance properties than non-composite polymers.
- The matrix in compositematerial for FDM, mostly consists of thermosetting and thermoplastic polymers.
- Production of complex shape products is easy in FDM because it works on CAD design and G-Code.
- Many researchers developed and formulated different types of 3D printers, designed 3D printers, process parameters of 3D printers, composites of material which are used in 3D printing, optimization of printing processes and testing of the finished product

3. Research Gaps

From the above literature review and a detailed study of different FDM composite materials and optimization processes, the following research gaps have been identified.

- Based onthe literature review for printing different materials by the FDM process, it was observed that very little research on waste tyrerubber-based composite material has been done.
- Recycling process of waste tyre rubber to ground tyre rubber exists in research papers but this GTR is used in concrete mixture to provide better adhesive properties for cement mixture for construction. However, the GTR as a reinforcement in thermoplastic

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polymers can be a better option to increase the abrasion and Impact strength of the material.

- There is no GTR-based polymer filament in this industry for the FDM process. This research can provide a better GTR-basedmaterial rather than thermoplastic. Because, in the 3D printed market, they charge a lot of money for thermoplastic filament. So, there is a need to develop a composite filament which is produced by waste reinforcement.
- Industry also trying to develop a fibre-based composite polymer that shows,the progress of 3D printed fibre reinforcement polymer composite.
- Recycling of some waste thermoplastic polymerwith Al_2O_3 reinforcement for rapid tooling applicationsresearch has been done but there is less research on GTR as a reinforcement in Polymer Matrix.
- No proper available techniques to convert waste tyre rubber into 3D printable GTR.
- There is no appropriate GTR composition (%) available with thermoplastic polymer for 3D printing.
- Proper selection will be needed for deciding the particle size(µm) of GTR with thermoplastic for FDM filament.
- From the literature review, lack of fatigue strength dataavailable for GTR-based composite material in additive manufacturing.
-

WORK IMPLEMENTATION

1. Methodology

The following steps will be followed for this research work.

- *Reinforcement Processing*

First of all, the waste tyre will be collected from the vehicle's scrap location. Rubber will be removed from a waste tyre with the process of grinding and that rubber part is called ground tyre rubber (GTR). Ground tyre rubber is the removed rubber from the waste tyre.

GTR will be prepared for blending from the grinding process. Cryogenicand ambient temperature grinding processes[20]can be used for the preparation of GTR. These grinding processes are available in waste tyre management industries.

This GTR will be used as **reinforcement** in this research work. GTR particlesize will be in microns because, for proper mixing with thermoplastics, the size of GTR should be in microns for better bonding.

- *Material Processing*

3D printable thermoplastic polymers as host material will be selected and these thermoplastics can be ABS,PLA, HDPE, and others. For example, waste of HDPE will be collected from home

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surroundings and industries. There is a lot of HDPE waste created around human beings surrounding such as waste shampoo bottles, waste plastic buckets, etc. ABSthermoplastic can be used as a host material.

These thermoplastic polymers will be blended with GTR reinforcement. After this blending process, the composite material will be developed for 3D printing. The blending process will be performed in a twin-screw extruder.

The proportion of host thermoplastics and GTR reinforcement material will be selected manually for blending in the extruderand will bebased on material flow index (MFI) and melting temperature.

Material flow rate and thermal testing will be performed for this composite material. Thermal testing will be performed by differential scanning calorimetry (DSC). DSC will give the result about what is the melting temperature of composite material.

The MFI and melting temperature should be matched with the FDM 3D printer because this is a basic requirement for printing the material on the FDM 3D printer.

- *Filament preparation*

When the MFI and thermal scanning of composite material are matched with the FDM printer then filament wire will be developed for 3D printing from the twin-screw extruder.

This filament wire will be suitable for FDM setup. The diameter of that filament wire will be around 1mm to 1.5mm. This diameter will be decided based on a 3D printer nozzle.

- *Sample preparation*

After filament preparation, the next step is to sample print by FDM machine. A sample of composite material will be prepared according to ASTM as standard sizes.

The sample will be printed at different printing process parameters such as printing speed, infill density, layer thickness, bed temperature, etc.

- *Mechanical Properties and Microstructure Testing*

Testing of printedsamples will be performed such as mechanical properties and microstructure images.

Mechanical Properties

Testing of printed samples will be performed by different mechanical testing machines. Testing machines such as Universal testing machine (UTM), Impact testing machine, Vickers hardness machine, and many more.

The tensile strength, compressive strength, fatigue strength, elasticity, elongation, bending strength, hardness, and toughness of printed samples will be tested.

Microstructure Testing

Microstructure testing will be performed on printed samples. There are different types of

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microscopic instruments to analyse the microstructure of samples such as Scanning Electron Microscopy (SEM), Raman spectrometer, Wavelength Dispersive X-ray Fluorescence (WDXRF) spectrometer, etc.

SEM is all about the microstructure image of the material surface. In this microscopic testing, the sample should be in the form of solid and powder. SEM will be used to know about the grain size and morphology of the sample.

This testing machine works on conductive samples. For non-conductive materials, make them conductive with the method of coating which is also available at SEM workplace.

2. Research process flow diagram

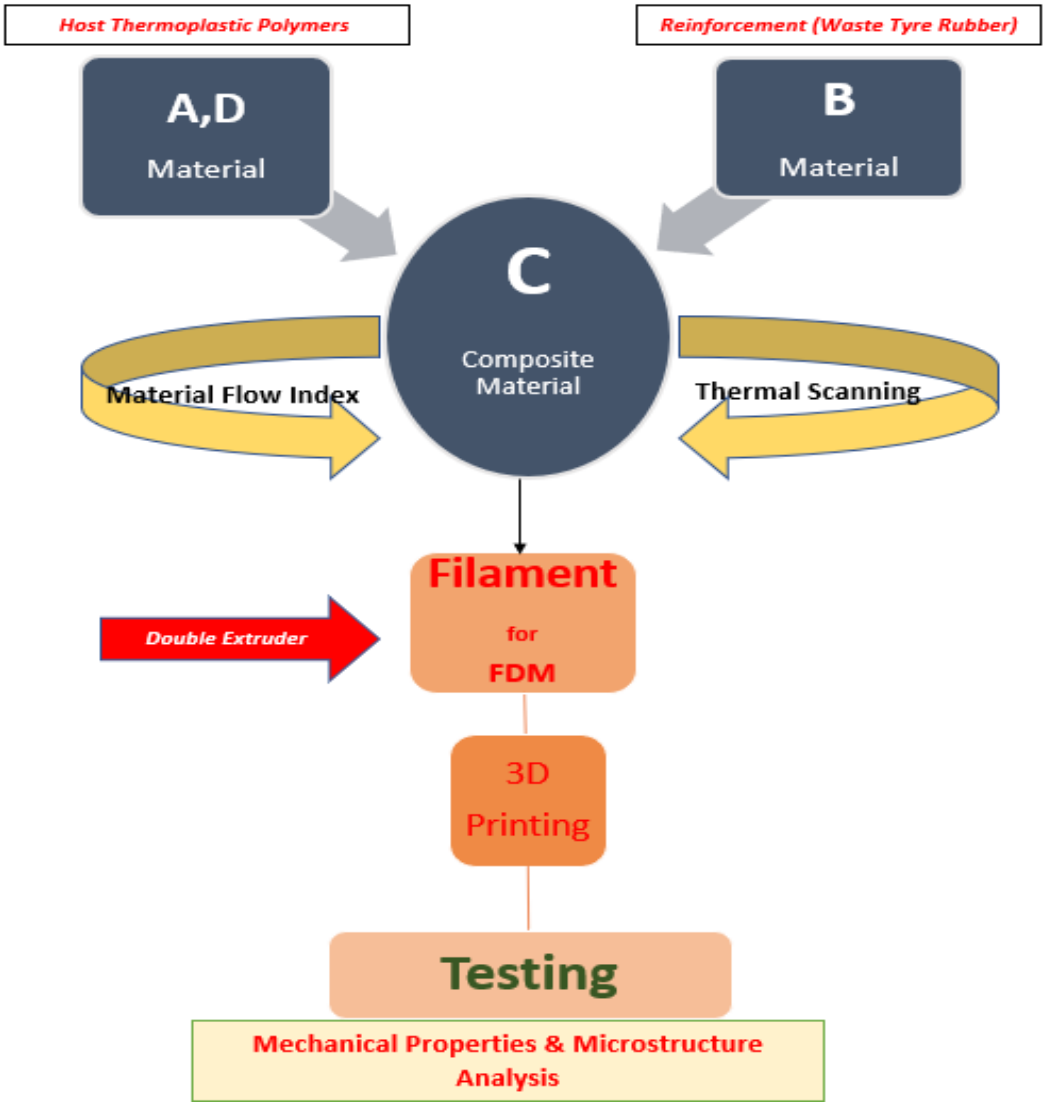


Figure 4 – Research process flow diagram

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CONCLUSION

From the current scenario of the automobile sector, the production, and use of tyres in vehicles become more and more, but this is not a problem. The problem of producing waste tyres from the automobile industry is the main concern. Due to this, more waste tyres come into living surroundings.

Waste tyres produce more pollution in the environment and this is a serious issue for the environment because wastetyres are toxic, flammable, and non-biodegradable.

Providing GTR from these waste tyres can be the best option to decrease this waste from this world. GTR can be used in thermoplastic materials as a reinforcement. So, there is a need to develop GTR-thermoplastic composite for the 3D printing industry which will help for solving environmentalissues and industry technology. This GTR-thermoplastic composite will be printed by the FDM process.

The printed GTR-thermoplastic composite will be used in different industries such as sports, education, and the manufacturing industry to enhance vibration and shock-absorbing capacity.

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AN EXPLORATORY STUDY: CHALLENGES FACED BY STUDENTS IN LEARNING A COMPULSORY SUBJECT OF BASICS OF ELECTRICAL ENGINEERING AT FIRST YEAR LEVEL OF BACHELOR'S DEGREE

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Abstract

Teaching a first year Electrical Engineering subject which is stimulating, interactive, and still covers the syllabus framed by the university can be a challenging but not difficult task. The undergraduate engineering subject in most of the universities includes a theory subject of Basics of Electrical Engineering in the very first year of the engineering programme. The students have to undergo its study along with a variety of multidisciplinary subjects of many engineering disciplines before entering into the curriculum of their particular field to acquire their degree in that particular field of engineering. This paper describes the challenges faced and methods needed to improve the performance of students. If identification of needs of students for learning the subject is done, the teaching and learning methods can be improved. More interactive learning environment approaches and deployment methods can be planned for the subject of Electrical Engineering. In this study, the authors undertook an extensive statistical examination to explore diverse facets of engineering education and their impact on student learning achievements. Emphasis on how to revitalize the students to involve in the learning process is essentially the foundation to the active learning process.

The authors of this paper aim to conduct a comprehensive investigation into innovative teaching and learning practices within engineering education, focusing on their impact on student engagement, conceptual understanding, and overall learning outcomes.

Keywords

Electrical Engineering, Subject Coverage, Deep Learning, Surface Learning, Interactive Learning.

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Introduction

Ensuring that the subjects offered to the newly entered first-year students and providing support to these new entrants in colleges and universities is of great concern for futurism. They need to remain appropriately pitched and the need for effective integration of technical expertise with a friendly atmosphere at graduation level in technical universities/ Higher Education Institutes (HEIs) is in great demand in the changing times, across the globe.

This exploratory study involves students of first year, learning a compulsory subject of Basics of Electrical Engineering at first year level of their graduation process in various colleges/ HEIs, affiliated to some local or foreign universities of repute. Irrespective of the Bachelor in Technology/ Engineering they are enrolled for; the students have to undergo the traditional instruction methods, practices and materials for reference in the subject [1], [2].

The objective of this exploratory study is to assess the learning experiences and challenges faced by first-year students enrolled in the Basics of Electrical Engineering course across various colleges and Higher Education Institutes (HEIs). The study aims to identify common misconceptions, difficulties, and gaps in understanding among students transitioning from school to college curriculum. Additionally, it seeks to evaluate the effectiveness of traditional instructional methods and materials in facilitating student learning in the subject. Through this investigation, the study aims to inform strategies for enhancing the integration of technical expertise with a supportive and conducive learning environment in technical universities and HEIs worldwide.

If the conventional practices of teaching the subject are followed, students are physically present but may remain passive; watching, hearing and still rarely thinking actively about the study material being presented on the board or through presentations.

Literature Survey

The authors discussed and analyzed the recent research papers contributing to the ongoing discourse on effective teaching and learning practices in engineering education, offering insights into innovative instructional approaches, technologies, and pedagogical strategies aimed at enhancing student learning outcomes, engagement, and inclusivity in engineering disciplines.

Smith et al. investigate the impact of the flipped classroom model on student learning outcomes in engineering education. The study examines the effectiveness of pre-class assignments and in-class activities in promoting active learning and enhancing student engagement and conceptual understanding [3].

Johnson and Patel assess the effectiveness of project-based learning (PBL) in the electrical

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engineering curriculum. The study evaluates the impact of PBL on student learning experiences, problem-solving skills, and application of theoretical concepts in real-world engineering projects [4].

Garcia et al. explore the integration of virtual reality (VR) simulations in teaching electrical engineering concepts. The study investigates the effectiveness of VR-based learning experiences in enhancing student engagement, spatial visualization skills, and understanding of complex engineering principles [5].

Nguyen et al. examine strategies for enhancing student engagement and collaboration in online engineering courses through interactive learning platforms. The study evaluates the impact of collaborative online tools, such as discussion forums and virtual group projects, on student participation and learning outcomes [6].

Kim et al. investigate the use of machine learning algorithms for personalized learning in engineering education. The study explores the potential of adaptive learning platforms and intelligent tutoring systems to tailor instructional content and support individualized learning pathways for students in engineering disciplines [7].

Wang and Li explore strategies for enhancing problem-solving skills in engineering education through collaborative learning. The study examines the impact of collaborative problem-solving activities on student engagement, critical thinking, and teamwork abilities in engineering courses [8].

Chen et al. conduct a meta-analysis to assess the effectiveness of active learning strategies in engineering education. The study synthesizes findings from a range of research studies to evaluate the impact of active learning approaches on student learning outcomes and engagement in engineering courses [9].

Li and Wu examine the challenges and opportunities of incorporating peer instruction techniques in large engineering classes. The study investigates the effectiveness of peer instruction in promoting student interaction, conceptual understanding, and peer learning in large lecture-based courses [10].

Zhang et al. conduct a systematic review to explore the role of gamification in engineering education. The study synthesizes existing literature to examine the impact of gamified learning experiences on student engagement, motivation, and learning outcomes in engineering courses [11].

Liu et al. discuss strategies and best practices for promoting active learning in engineering education. The paper highlights the importance of implementing active learning approaches,

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Such as problem-based learning, peer instruction, and flipped classroom, to enhance student engagement and learning outcomes in engineering courses [12].

Wang and Chen examine the challenges and solutions of adapting engineering curriculum for online learning. The study identifies key challenges faced by engineering educators in transitioning to online instruction and proposes effective strategies and technologies for delivering high-quality engineering education in virtual environments [13].

Zhao et al. explore the role of robotics in engineering education by reviewing recent trends and innovations. The study examines the use of robotics-based learning experiences to enhance student engagement, problem-solving skills, and interdisciplinary learning in engineering courses [14].

Li and Patel discuss strategies for addressing equity and inclusion in engineering education to support underrepresented students. The paper examines the challenges faced by underrepresented groups in engineering and proposes effective interventions and support mechanisms for promoting diversity and inclusivity in engineering programs [15].

Wu et al. explore the integration of data analytics in engineering education, highlighting opportunities and challenges. The study examines the use of data-driven approaches to enhance teaching, learning, and assessment practices in engineering courses and discusses potential implications for curriculum design and pedagogy [16].

Chen et al. assess the impact of active learning spaces on student engagement and learning outcomes in engineering education. The study investigates the effectiveness of innovative classroom designs, such as collaborative learning environments and flexible seating arrangements, in promoting active learning and student success in engineering courses [17].

Students' Ability and Learning Methods

From the mid-nineties to the end of the twentieth century, when engineering colleges were a few and would have a few highly selected students, in each engineering subject, the conventional lecture followed by tutorial seemed to work well enough. With the flood of engineering colleges since the beginning of 21st Century, students get admission in some colleges, somehow. The intake quality has therefore deteriorated with colleges providing admissions without appropriate quality checks for revenue reasons. Also, with the availability of gadgets and electronic devices, a new generation of students finds it difficult to manage their time between studies and e-recreational activities. Dense and quite diversified student population in a classroom, with not many students capable to cope with the syllabi and so many subjects per semester, with teachers feeling that these students should not be at university at all, the question which we as faculty members often face is whether the students will successfully get good grades or pass the subject

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and who are going to survive in the race. Two learning approaches shown by the students include:

A. Deep Learning Approach

The student is academically committed; shows interest in the subject, does regular study, and overall does well. The academic plans are well set, and whatever is learnt in the classroom is important. The approach is purely academic. The student comes to the lecture with prerequisite knowledge and a framed question in his mind that he as a learner desires to be answered with enough logic and explanation by the faculty. If during the lecture hour, an answer is found to that question; he is satisfied and a guided arch of knowledge is well constructed. Such students virtually teach themselves and need only little help from professors.

B. Surface Learning Approach

Unfortunately, most of the students at the HEI do not join out of a burning desire about a particular subject, or to excel in a particular profession, but to obtain merely a qualification/ degree for a job or have been compelled due to social status . They may even not be studying in the area of their first choice; as a student who wished to join Computer Science may have been compelled by his father to join Electronics Engineering just because the father wishes so. Such a student is bound to show less commitment and interest in studies than any student belonging to the first category. He is going to have a less developed background of relevant knowledge; he likes to come to the lecture with no questions to ask. He puts in just sufficient effort to clear the subject in university exams. Most of the time, he hears the professor say some words which are of no interest to him but simply records them as the professor has asked him to do so in his notebook.

At college level, a surface-learning approach is preferred and easy to follow for most of the students rather than a more conceptual approach Unfortunately, students are not prepared to abandon the surface learning approach and go with a deep learning approach, for a larger success [18], [19].

Challenges Faced By the Students in Effective Learning

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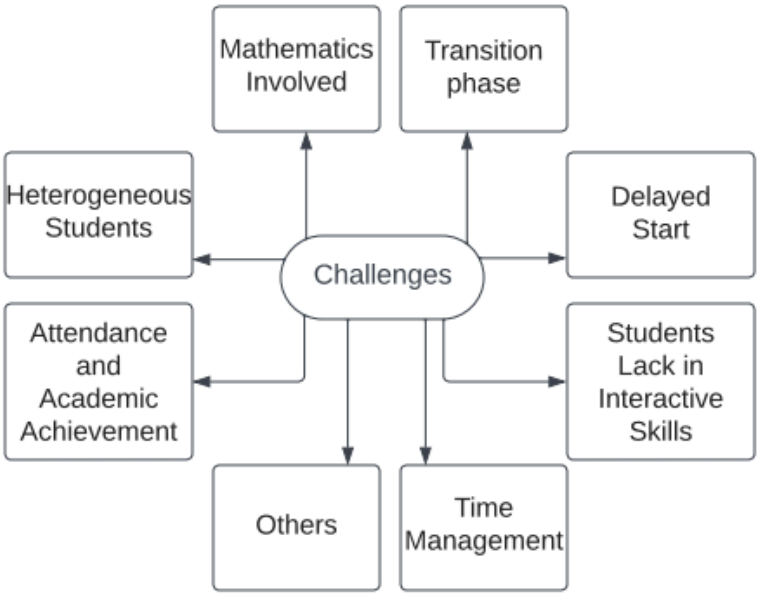


Fig1. Challenges faced for effective learning.

The challenges faced by the students in effective learning, in general about the particular subject of Basics of Electrical Engineering have been revealed in Fig.1. The authors reveal the challenges faced in a subjective manner.

A. Mathematics Involved

While teaching a subject on Electrical Engineering Basics, faculty often has a tendency to emphasize on the mathematical analysis of the problem. The students, not so keen in solving mathematical problems, get lost in the mathematics involved. They usually can perform the calculations, but spend a lot of time in solving, then on understanding underlying concepts and often do not identify the correct connection between the mathematical statements and the actual engineering problem. Students often have a hard time in setting up a problem and determining what is necessary to solve it. Many times they find solving vector calculations not an easy task, fail to understand phasor additions/ subtractions/ multiplications or divisions and forget the formulas needed in the numerical problems. The students are often lost in polar or rectangular form to be used while performing calculations with ac quantities.

The anecdotal conversations with students during the semester support the above statement. In tutorials and after lectures, comments were made regarding the solving of numerical problems on Mesh Analysis and Nodal Analysis:

- I am considering Electrical Engineering as my favorite subject at the moment, but

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solving these 3 by 3 equations makes me feel bored.

- I have understood how to apply Mesh analysis and Nodal Analysis but solving for three currents is cumbersome.
- I am still confused between lagging and leading power factor circuits' and related analysis
- I do not want to apply the phasor method for solving the vector equations, can I solve them using simple arithmetic rules?
- We frequently get confused between series and parallel circuits.
- Single phase ac circuits were themselves not so easy to digest, now who can understand three phase ac circuits.
- Formulation and analysis of dc circuits is understood but when it comes to ac circuit analysis, students find it tedious, time taking, confusing and calculations as too long.

Also, star to delta conversions and vice-versa, relationship between line and phase values of three phase voltages and currents and phasor diagrams is difficult to be understood by many.

B. *Transition Phase (School to College)*

Some students do not find it easy to adapt themselves to a new classroom environment in college, altogether different from a school environment. Many are living in hostels for the first time; some are sharing a room with a new person whom they do not even know well. Most of them are learning the classroom norms, college norms and department norms and maybe hostel norms too. A few students begin redefining their way of learning as previous ways do not work well.

C. Delayed Start

Most of the students view the lecture as a repetition of the text and physical attendance as the goal and sleep through the lecture hour or work on other assignments or lab reports' preparation during that time. Thus, poor study habits and bad time management makes them lag behind [20].

D. Students Lack in Interactive Skills

Some students feel too embarrassed or too shy to ask for help and never interact. Inexperienced students believe that they can handle any difficulty on their own, but may find that the difficulties grow progressively and have cumulative worse effects on their performance in the assessments made each time.

E. Time Management

An additional issue that students may have is how to manage their time effectively. The sudden change from a yearly system of studies and assessments to either semester based or trimester based system is not so easy for most of the students to adapt to.

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F. Attendance and Academic Achievement

One reason for the differences in academic achievement shown by the students may be due to the variations in students' attendance. It has been reported that students' attendance significantly correlates with their academic achievement. Students, who attended the most, achieved the highest marks. Maintaining continuity in studies for effective teaching and learning practices is the key to success.

G. Heterogeneous students' in a Classroom

Some students in a class are quick learners, whereas some have a slow pace to grasp, some are passive learners and some are active, some have communication issues, etc. Some students have language problems because of the teaching practices in native languages at school level and suddenly they find the subject is being taught in English as the medium.

With these and many other unsung issues, the students realize they had either not done well in the internal exams scheduled and held by the college and probably will be incompetent to do fairly well in the external theory exam as well. The first internal exam result may itself be treated as a wake-up call by the poorly performing students. Many students even rationalize their poor grades by simply "forgetting" instead of "understanding" and "identifying" the reasons for the same. If they do so and learn the laws and apply the concepts properly, the results in the next assessment will definitely show an upscale trend.

Factors of Feedback for Effective Teaching and Learning

If analyzed statistically to investigate the possible effects of factors that affect the feedback of professors' teaching are categorized as shown in Fig 2.

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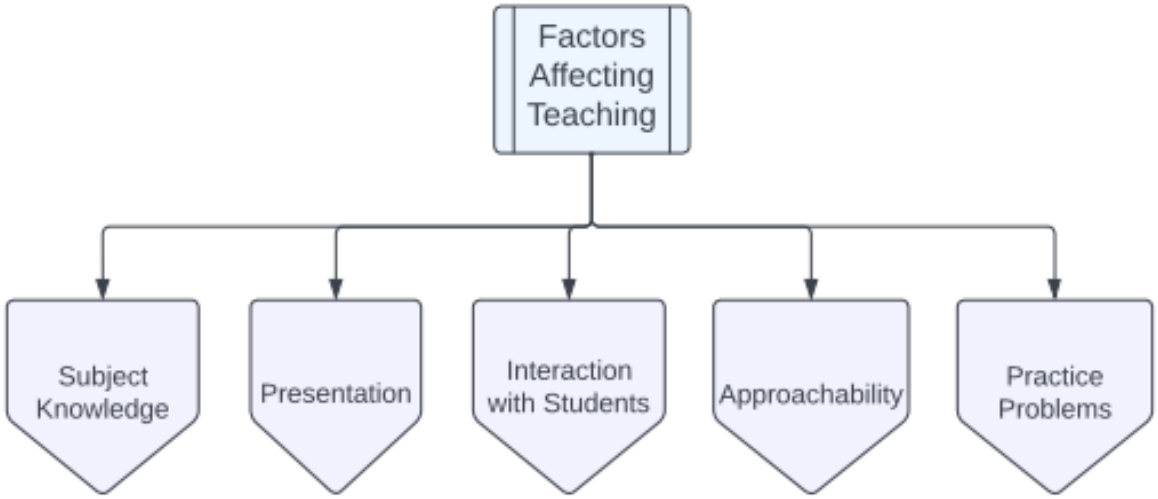


Fig 2. Factors of feedback for effective teaching and learning

A. Subject Knowledge
1) Knowledge in the subject
2) How effectively the lecture is delivered?
3) How easily does the professor cope up with problems raised by the students?

B. Presentation
1) Voice
2) Eye Contact
3) Posture
4) Communication Skills

C. Interaction with the students
1) Attitude
2) Mentoring ability
3) Permission to Interrupt
4) Is practical relevance discussed?

D. Approachability to Students (Outside the Classroom)
1) Solving Difficulties
2) Giving time after college hours or on off days
3) Approachable for personal discussions

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E. Practice Problems

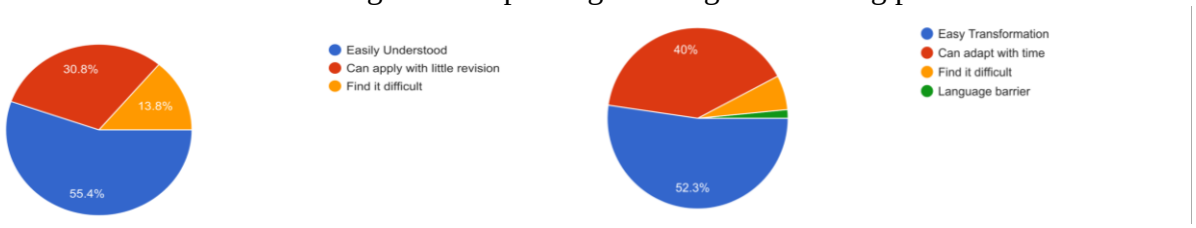
1) Care and concern for all the students
2) Solving number of problems in the classroom
3) Practice Problems given by the faculty
4) Guidance for problem solving

Although the majority of faculty are indistinguishable, a few others are consistently different from this majority. Some significant observations are made from these questionnaire ratings, and may be used for the improvement of the quality of teaching and creating a simulating, exciting and interactive learning environment in the subject of Electrical Engineering.

Assuring that the students fill the information with a candid response which serves as a great source of input for the faculty to improve.

Statistical analysis

In this paper, the authors conducted a comprehensive statistical analysis to investigate various aspects of engineering education and student learning outcomes. Utilizing quantitative research methods, the authors employed descriptive statistics to characterize the prevalence and distribution of challenges faced by students transitioning from school to college curriculum, experiencing delays in starting their studies, and struggling with mathematical concepts. Additionally, inferential statistics were employed to examine the relationships between factors such as attendance, student-faculty interaction, and academic performance. Through regression analysis, the authors explored the predictors of student success, including the impact of time management skills, approachability of faculty, and availability of guidance for problem-solving. Moreover, analysis was conducted to assess the associations between different variables, such as student attendance and learning ability, and the effectiveness of faculty-student interaction in facilitating learning outcomes. The statistical analysis (Fig 3) conducted in this study provides valuable insights into the factors influencing student success in engineering education and informs evidence-based strategies for improving teaching and learning practices in the field.



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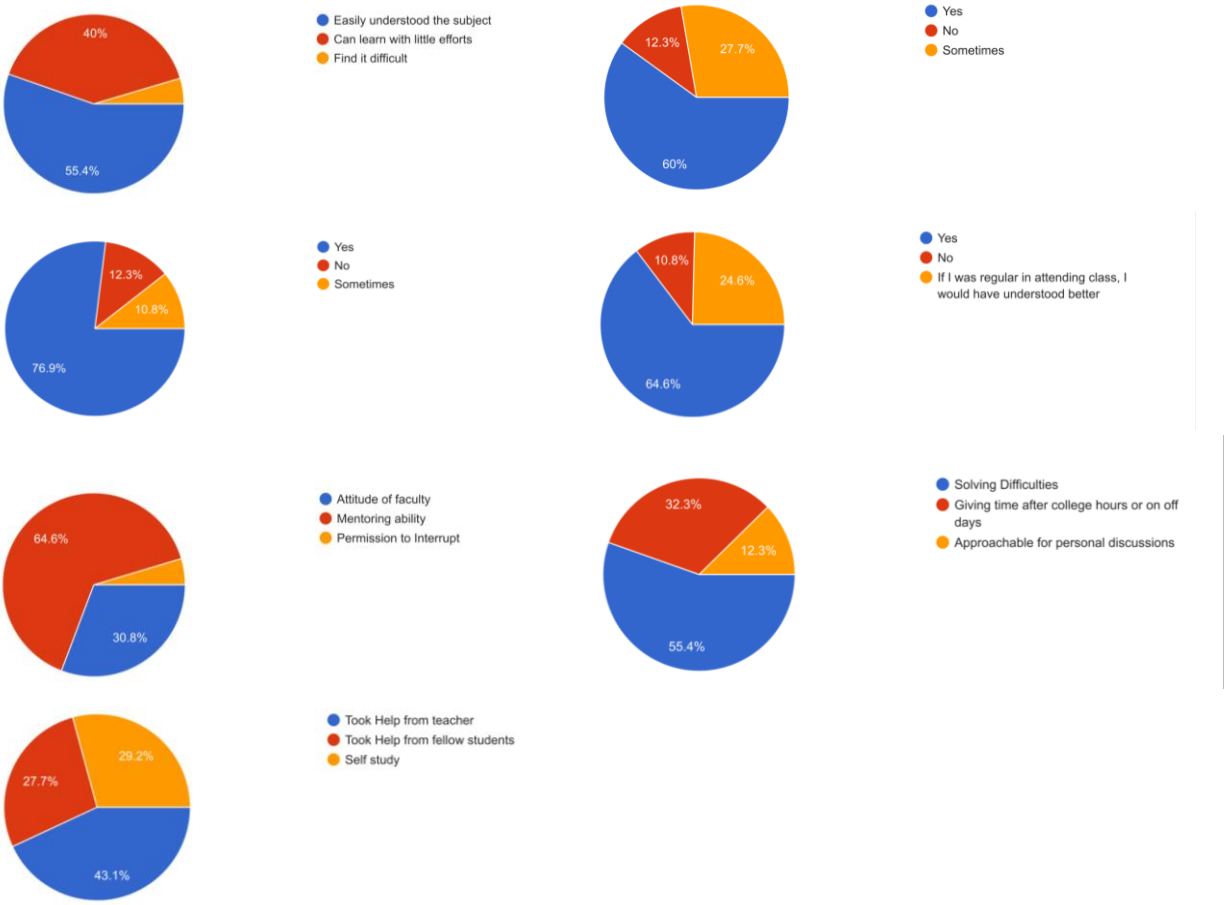


Fig.3 Results of statistical analysis

Conclusions

The outcome of the exploratory study reveals the prevalence of robust and pervasive misconceptions among students in engineering education, transcending individual, institutional, and national boundaries. The study highlights that fundamental concepts such as current, voltage, series and parallel connections, as well as distinguishing between DC and AC circuits and their excitation and response characteristics, are poorly understood by a significant number of students. Addressing these misconceptions is crucial for students to progress to more advanced engineering concepts effectively.

The study emphasizes that understanding the incorrect models underlying these basic

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misconceptions is the first step in correcting them. By implementing appropriate subject interventions and comprehensive planning for subject coverage, examination results demonstrate that such misunderstandings can indeed be corrected. Moreover, the study suggests incorporating outside class activities, such as sharing lecture notes and preparing presentations on lighter topics, to facilitate collaborative learning and reinforce understanding.

In conclusion, the outcomes of the study underscore the importance of targeted interventions and comprehensive teaching strategies in addressing fundamental misconceptions in engineering education. By implementing these strategies, educators can effectively support students in mastering foundational concepts and preparing them for success in more advanced engineering studies.

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PROCEEDINGS OF 10TH INTERNATIONAL SYMPOSIUM ON FUSION OF SCIENCE AND TECHNOLOGY (ISFT-2024)
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AN EXPLORATORY STUDY ON CREATING AN INTERACTIVE LEARNING ENVIRONMENT IN LECTURES FOR FIRST-YEAR ELECTRICAL ENGINEERING SUBJECT

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Abstract

This paper describes an ADRI approach and a typical Subject Coverage and Improved Performance Algorithm for Electrical Engineering theory subject that will upscale and enhance the learning abilities of the learners. The statistical analysis and discussions taken up in writing up this paper may contribute to the success, and students' willingness to study Electrical Engineering subject with positive and harnessed human energy efficiency. Some guidelines have been framed for the teaching fraternity involved to improve the performance by creating an interactive learning environment.

Keywords

Electrical Engineering, Subject Coverage, Graduate Attributes, Improved Performance, Learning Outcomes.

Introduction

Relatively less efficiency and effectiveness of teaching are the outcomes of engaging the students in a classroom in a traditional way. Information received with no active participation leads to either sudden loss of lecture content or no interest in future subjects offered where Electrical Engineering subject related knowledge and expertise in analytically solving the problems is a pre-requisite. The traditional method of teaching the subject uses lectures, laboratories, assignments on daily basis and demonstration models to illustrate the essence of electrical engineering. This paper describes typical Subject Coverage and Improved Performance Algorithm (SCIPA) for electrical engineering theory that up scales and enhances the learning abilities of not so keenly liked subject of electrical engineering by the students universally.

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The general observation is that the unidirectional flow of information from the faculty to the student does not motivate or encourage the students enough to participate as an active performer in the learning process, especially if the students are not doing or intend to do majors in electrical engineering in higher studies. The teaching fraternity has to explore new ways of developing a stimulating and interactive learning environment for students' attention during lectures [1], [2]. If this is not done by the faculty involved in teaching in a classroom that comprises of not so actively participating students, interest for the subject continues to decline in the subject coverage; week by week.

The study materials provided and the strategies used in teaching need to be so designed to synchronize conventional practice of taking the notes and motivating the students to solve problems and actively participate in the class room. Enabling the students to solve some problems on the topic covered, then and there or in the subsequent tutorial class, providing reference guided notes by the faculty used in the subject and simultaneously stimulating students to actively engage will definitely enhance their learning abilities [2].

The basic teaching and learning pattern being evolved by this study includes three additional ingredients, which are not present in the standard methods of teaching.

- First, it includes questions that prompt or activate students to assess their knowledge.
- Second, it enhances regular attending and assessment of the students.
- Thirdly, not so regular students will also have a check meter running for them by the faculty in the theory or tutorial class.

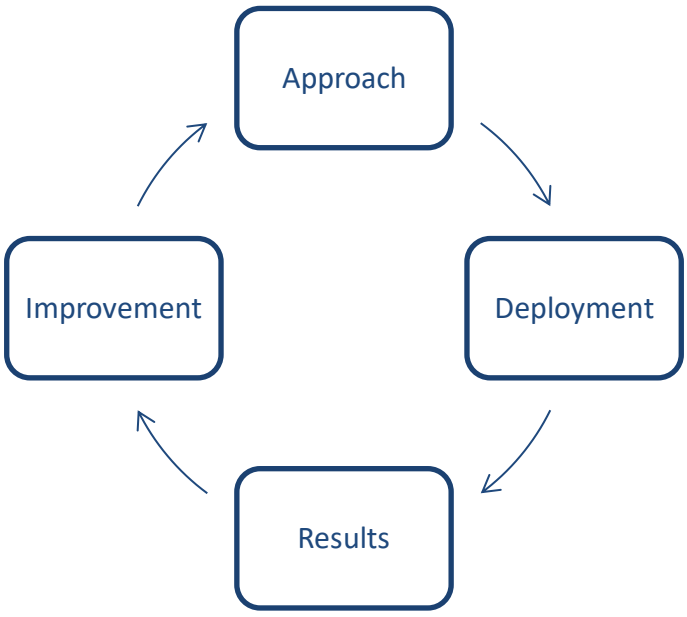


Fig.1. ADRI Cycle for effective teaching

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ADRI Cycle in Teaching

This section discusses the teaching skills required by the faculty involved in teaching this undergraduate subject. Major difficulties in maintaining academic standards for heterogeneous set of students in classes, the problem can be handled if learning outcomes (LOs) are mapped as a function of students' activities than of their fixed characteristics. The faculty has then to organize the teaching and learning methods and the subject content so that all students are involved in a higher order learning process. Academic students use skills spontaneously to produce a rewarding outcome and not- so- academic students also are a part of the learning process. It would be appropriate to apply an ADRI cycle (Fig.1) followed in quality circles often to meet the desired outcomes of increased human learning and performance in teaching subject on Electrical Engineering, in specific or for that matter any other similar subject to be offered and taught; with similar challenges.

A. Approach

Subject plan, subject handout, assessment methods, guided notes-module wise, soft or hard copies of tutorial problems and assignments; individual or group based, previous year question papers, peers groups of students, all need to be organized as approach documents. These may be revised based on the outcomes achieved from the previous year's results.

B. Deployment

All the documents which have been enlisted as approach documents will be deployed/ implemented by the respective faculty with an objective to produce some tangible outputs. For effective classroom delivery, Fig. 2 can be followed. Next section in the paper emphasizes on Deployment skills to be demonstrated by the faculty.

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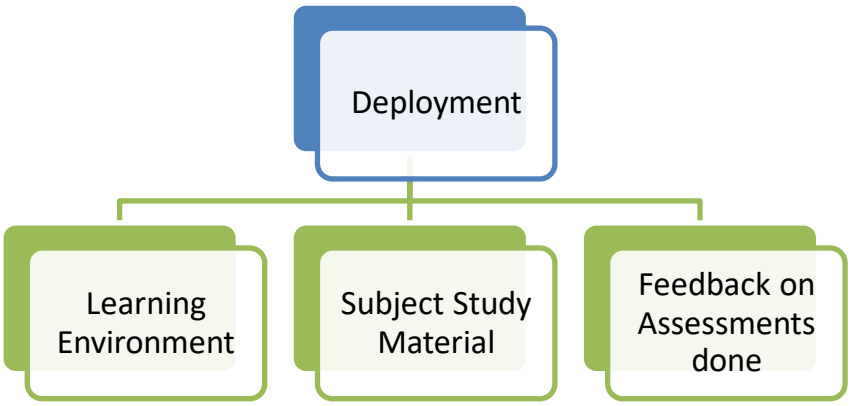


Fig. 2. Key elements of Effective Deployment

C. Result

Some mechanism to review the outcome of deployment of approach activities through meeting with students or feedback, in general, has to be planned at the department or institute level and with a mechanism to inform both the parties involved for further improvements based on the suggestions provided by the students. Taking feedback, and including it as a continuous improvement, integral and important aspect in the delivery of quality education. The evaluation of faculty performance is carried out by students through some sort of anonymous questionnaire and is a procedure that has become established at many Colleges in the University. This produces numerical data that are used to classify the relative teaching effectiveness of the members involved in teaching.

Likert scales can be effectively used with a range from:1(Strongly Disagree) to 10 (Strongly Agree). Some objective type survey questions can also include some key aspects such as:

1) Presentation of the lecture/teaching was helpful in learning
2) Teaching methods used by the faculty member were effective
3) Discussions in classroom teaching were encouraged by the faculty member
4) Assignments given were relevant to the subject content
5) Subject Handouts, guided notes and study material provided by the faculty member were useful
6) Faculty member was clear and easy to understand
7) Teaching was at appropriate pace
8) Faculty member is easy to approach in case of any support required
9) Faculty member is punctual
10) Faculty member engages the class for the full period
11) Faculty member comes well prepared for the class
12) Feedback given on my performance in assessments undertaken by me and assignments

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submitted has helped me to improve in the subject taught

Some subjective questions can also be added to take students opinions and frame the lectures accordingly.

1) The best features of this subject
2) Your suggestions for further improvement of this subject
3) Any other suggestions which make the subject easy to understand for students' community at large

D. Improvement

Improvements can be made for future actions, after assessing the results. This process will be carried out through detailed analysis given by students in the surveys, self-analysis, peers'-analysis (if conducted in the HEI) and any other way.

DEPLOYMENT OF TEACHING SKILLS

The basic electrical engineering subject covers the study and application of direct (dc) and alternating current (ac) circuits and concepts, both single phase and three phase ac circuits, the circuit fundamentals, theorems, laws, methods of analysis, knowledge of behavior of active and passive components, basic principles involved in various types of measuring instruments, magnetic circuits, single phase and three phase circuits' analysis, construction and operating principles of transformers and electric machines such as dc machines, single phase induction motors, three phase induction motors, synchronous machines and introduction to power systems. Lab activities include analysis of dc/ac circuits, verification of Theorems such as Thevenin's Theorem, Norton's Theorem, Maximum Power Transfer Theorem, Reciprocity Theorem, etc.

Also, the students are demonstrated to learn the use of measuring instruments, power supplies, and signal generators. Upon completion of this subject, the students should be able to understand, but not limited to, the following:

1) Demonstrate an understanding and application of Ohm's Law, Kirchhoff's laws, Nodal Analysis, Mesh Analysis
2) Demonstrate an understanding and application of Resistances, active and passive elements, open circuits and short circuits
3) Demonstrate an understanding and application of series, parallel, and series and parallel circuits
4) Understand the principles of capacitance and inductance in dc and ac circuits
5) Understand the principles of single phase and three phase ac circuits
6) Demonstrate the ability to use measuring instruments

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7) Understand the construction, principles, working, characteristics and area of application of dc motors, dc generators, three phase induction motors, single phase induction motors and synchronous generators and synchronous motors
8) Understand the construction, principles, working, emf equations, vector voltage and current equations and phasor diagrams for single phase transformer

The essential teaching skills expected from a faculty to undertake the effective deployment include many skills. These skills will help student attain graduate attributes such as Engineering knowledge, problem solving ability, analytical thinking, time management, individual and team work, creating sustainable designs, development skills and lifelong learning, etc. to name a few.

A. Subject knowledge

1) Knowledge of concepts
2) Potential to communicate this knowledge effectively
3) Deliver the content in ways appropriate to the learners
4) Ability to solve problems and solutions, as and when asked by the students, as individuals or in groups
5) Provide diversity in problems

B. Subject plans and lecture planning

1) Ability to prepare subject plan
2) Individual lecture sessions that fulfill subject objectives
3) Employ teaching practices to which classroom adapts to methodology
4) Satisfy learners' requirements in the subject.

C. Class management

1) Ability to control and facilitate teacher–learner interaction in the classroom
2) Create interest across length and breadth of classroom and not only cater to group of academic students only.

D. Promoting learners' autonomy

1) Usage of appropriate teaching materials and strategies to help learners achieve their learning objectives.
2) Promote independent and group learning.

E. Learning Interface

1) High level of commitment to providing education which best reflects the need of first year students.

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2) Taking extra classes or remedial classes or compressed classes for the students not performing so well in the classroom and as revealed from the assessments.

F. Assessment and evaluation of learning

1) Ability to plan and employ appropriate and timely evaluation and assessment at various stages in the learning process.
2) Giving feedback to average and below average performers to help them improve in other assessments.
3) Encouraging students to solve on the class room board, draw phasor diagrams for a leading circuit; if it has been explained for a lagging circuit or let the students draw connections' diagram and hence write equations for a shunt generator; if series generator has been explained thoroughly.

G. Student motivation

1) Encouraging them to prepare for class room presentations on topics such as measuring Instruments
2) Ability to give priority to students needs and understanding what makes them work
3) Ensuring their continued engagement in teaching and learning process.

H. Learning new teaching technologies

1) Integrate new teaching approaches into subject content delivery.
2) The key tasks of the faculty are to create a Problem Based learning (PBL) Environment, through interactive classes and the use of technology, books, developed practical exercises and projects, and online teaching and learning resources or Information technology. Online resources and videos shown on construction and working of dc machines or ac motors are best learnt by the students. The faculty may even organize tutorials and small groups learning and decide to take up other tasks as and when required as per the class to be handled. This final leads to appropriate, positive and significant way to the development of the interest in the students for solving the problems pertaining to the subject.

I. Other Attributes

1) Ability to interact with other subject specialists and discuss subject handling techniques.
2) Maintaining academic integrity
3) Maintaining high degree of professional judgment
4) Being approachable to the individuals, group of individuals and the system
5) Being sensitive to the students with special needs
6) Honesty towards profession
7) Mentoring I year students who have started their higher education
8) Organizing Tutorials and small groups learning sessions
9) Being responsible to discuss the problems on 1:1 basis with the students.

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SUBJECT COVERAGE AND IMPROVED PERFORMANCE ALGORITHM (SCIPA)

SCIPA follows some steps with the sole aim to effective teaching and about inspiring students to want to learn, creating a desire to learn and be in the category of academic and active learner students. It also assures that well expressed and intended Learning Outcomes (LOs) and Graduate Attributes (GAs) can help to know students to what they need to learn, and also why they need to learn.

1) Spend first lecture hour to break the ice and develop teacher-learner bond
2) Distribution of Subject Handout and Lecture Plan Hard or Soft copy
3) Distribution of Tutorial problems/ Assignments/ Objective type problems on each module/ chapter/ unit as soft or hard copy.
4) Say, the faculty has to start Module 1. Decide whether today's lecture needs any priori knowledge. If yes, for the interest of the students, be prepared to deliver the same for a while and then continue with actual subject content on the respective module started. This enables students to analyze, justify, relate, correlate and apply concepts better. Continue as per the lecture plan for the module.
5) Discuss doubts of students. Teaching involves working out how to get students working on the problems and thus engaging them in active learning. When students have the opportunity of doing practice, it is more likely that they will then learn faster and forever.
6) They can even be asked to bring their doubts on Tutorial problems and assignments and Objective type problems after completion of same module or unit.
7) Announce for an assessment test for that unit. Providing feedback can correct their mistakes and misconceptions, provides them to have perfecting skills for the final or end term assessments.
8) Repeat steps 5 to 7 for the next modules.
9) Before the students master the subject, teaching fraternity needs to master the skills that when students gain a new level of understanding as they look forward to and have received the information with almost no loss; the burning desire to learn and gain knowledge is flamed.

Assuming that the faculty taking up the subject has an interactional and an institutional concern, the important points are summarized.

1) Conceptualizing students' conceptual understandings of threshold concepts
2) Students' likes and dislikes regarding student-activating
3) Lecture-based educational settings
4) Consequences for students' perceptions of the learning environment
5) Academic achievement among first semester undergraduate students.

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Conclusions

Other factors which can show improved performance are enlisted below:

1. Discuss in the beginning, during subject coverage, in the labs or even through mails that you want to meet them individually and also tell them the benefits of such meets.
2. Being approachable and showing interest in dealing with the students' problems is likely to increase their attendance in your office and their motivation to work harder on the subject. Students will show an improved performance in the subject.
3. Distribute notes, semi notes, presentations, guided notes, whenever necessary. Students feel that the professor is working hard for them and are in-turn ready to put in hard work themselves.
4. Motivate poorly performing students to show up during office hours some assignment or numerical problems. Research shows that such meets can further yield an improved response by at least another 10%; although response rate may be 75-80%.
5. Semester system is short and hence the professors need to be flexible to adjust to the rhythm of the semester and be ready to schedule extra hours during weekends or evenings after college hours. Many students are likely to turn up with loads of problems just before Assessments or Sessional Exam or University exams and their problems have to be addressed to show better results.
6. The faculty members have to put extra little efforts to build an exemplary image by his code of conduct, confidence in the subject, willingness to solve the problems, preparedness to deal with their conceptual problems and being respectful to them in the lecture or office hours so that they come again and again Establish a routine for dates, distribution of tutorial sheets, assignments, and solution sets so that students can also plan well the subject contents.

We finally conclude that a typical ADRI Cycle approach in subject coverage Subject Coverage and Improved Performance Algorithm (SCIPA) for electrical engineering theory will upscale the learning abilities of electrical engineering by the students universally if attributes are followed and algorithm is applied by both the teaching and learning members of the university or HEI.

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ISFT EE - 86

IoT Based Bluetooth Controlled Rover for Smart Farming Applications

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Abstract

Smart farming controls advanced technologies to optimize agricultural processes and enhance crop yields. IoT based solutions are pivotal in achieving precision farming by facilitating real time data collection and analysis. The integration of IoT in agriculture has the potential to revolutionize traditional practices equipping farmers with immediate data and insights. These insights are useful for effective resource management. Monitoring parameters such as soil moisture, temperature and humidity is crucial for maintaining an optimal crop environment. This helps in contributing to disease prevention and promoting optimal growth. In this paper, IoT based Bluetooth controlled rover is made for smart farming applications. The rover integrates various sensors including soil moisture, temperature, humidity and GPS to monitor and collect real time data. The data is uploaded to the Thingspeak cloud platform enabling remote access and monitoring.

Keywords

Smart farming; Data analysis; Optimal crop growth; Sensor integration

Introduction

In modern agricultural practices, the inclusion of Internet of Things (IoT) technology and farming practices has given rise to a new era of precision farming. These methods are transforming the traditional methods into smart and data driven approaches. The increasing worldwide population is placing significant demands on food production. [1-3] For this it is crucial to prioritize sustainable and effective agricultural methods. The integration of IoT technology in farming has emerged as a revolutionary way to address these difficulties. It provides real time monitoring, control and data analysis capabilities that reinvent the approach to agriculture in the 21st century. [4] The introduction of IoT in agriculture represents fundamental change in the way physical equipment/devices and digital platforms may communicate with each other. In the agricultural environment, the IoT enables the development of intelligent ecosystems where various devices, sensors, actuators and communication modules work together. [5] This leads to improving the accuracy and

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effectiveness of farming activities. The IoT enables farms to become cognitive entities that can adjust to changing environmental circumstances. Smart farming refers to the management of farms with the use of modern information and communication technology. It is used to improve both the quantity and quality of the goods produced while simultaneously reducing the amount of manual labor needed. [6] Figure 1 shows components of smart farming.

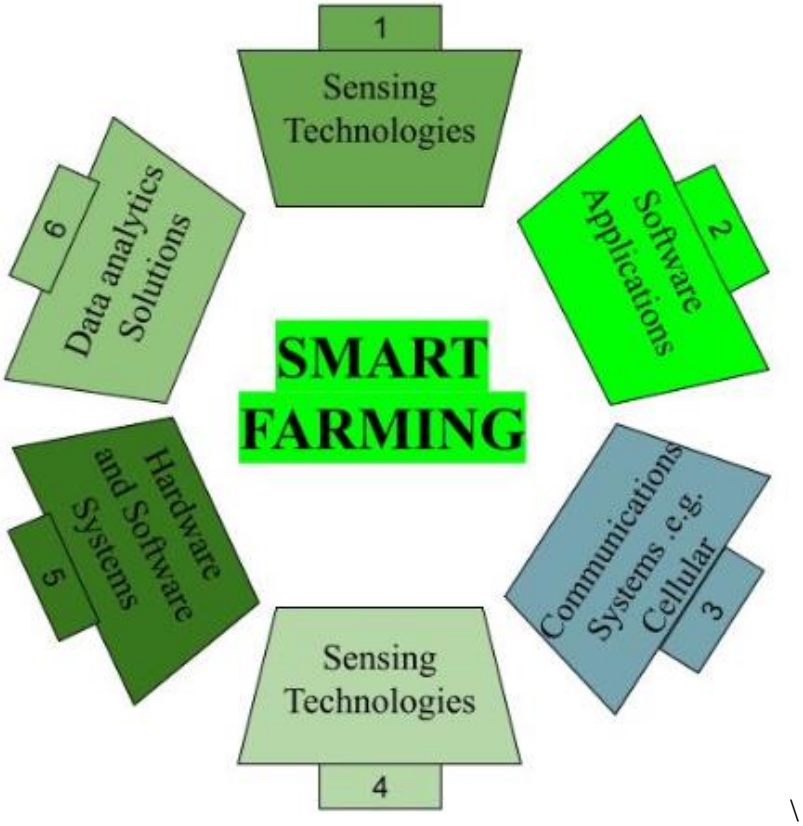


Figure 1. Components of smart farming

Challenges and Need of Smart Farming

Modern agriculture faces complicated issues like unpredictability of climate change, decreasing natural resources and increasing need for higher food. The conventional agricultural practices that functioned effectively in the past are becoming inadequate. The need of the hour is a shift towards a more data centric approach. In which real time data becomes the cornerstone of decision making processes. [7-8] The IoT meets this crucial requirement by offering a solid framework for gathering, sending and analyzing data from a wide range of agricultural characteristics. Farmers can make choices based on real time information. The deployment of sensors throughout fields and developments in data analytics leads to smart farming techniques. IoT enabled farms become data driven decision making centers. From anticipating ideal planting seasons to detecting sections of the field that need specialized treatments. The use of IoT in agriculture goes

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beyond the immediate demands of particular farms. [9] It lays the groundwork for a networked agricultural environment in which data from many farms may be pooled and analyzed on a larger scale. This macro level study may provide information on regional climatic trends, agricultural disease outbreaks and best resource allocation techniques.

The careful collecting and compilation of data on cloud platforms is a critical part of IoT based precision farming. This procedure requires the constant collection of data from sensors placed across the agricultural landscape. Encompassing a wide range of characteristics such as temperature, soil moisture, wind speed and crop health the data can be collected. [10-13] The acquired data is subsequently sent to cloud platforms where it is stored, processed and made available for further analysis.

The cloud platform acts as the primary nervous system of an IoT enabled smart farming. This acts as a centralized repository for the massive volumes of data provided by sensors. [14] This centralization allows farmers to make choices remotely by monitoring agricultural conditions in real time. The integration with cloud allows large scale data storage that would be hard to store locally. The historical data is easily accessible for trend analysis and long term planning. The benefits of cloud based data collecting extend beyond individual farms. Cloud based systems allow for the establishment of shared databases which enables farmers to contribute and access collective data. [15-17] This collaborative approach to data sharing may result in important regional or even global insights. Farmers, Researchers and Governments can discover trends, make forecasts and create methods for reducing the effects of climate change on agriculture. The utilization of cloud platforms improves the scalability and flexibility of agricultural IoT systems. As the number of linked devices and sensors on a farm grows, cloud based architecture guarantees that the system can adapt and handle the rising amount of data.

The data obtained from IoT devices is a useful source for farmers, agronomists and researchers. The abundance of this data empowers farmers to transcend basic correlations and explore intricate patterns that influence strategic decision making. The correlation between temperature and wind speed can be analyzed to understand how specific weather conditions impact crop growth. [18] The insights derived from data analysis contribute to a deeper understanding of the factors influencing crop health, growth patterns and overall farm productivity. Histograms depicting temperature variations over time provide a visual representation of climate patterns. [19-20] A histogram is a graphical representation of the distribution of data that allows for easy interpretation of patterns, trends and the underlying structure of the dataset. It is particularly useful for understanding the frequency or probability distribution of a set of continuous or discrete data. For precision farming applications creating a histogram for temperature variations over time involve organizing and visualizing temperature data. [21] The data produced in such a way that it provides insights into the frequency of different temperature ranges during specific time intervals.

Literature Review

In recent years, the integration of Internet of Things (IoT) technologies in agriculture has given rise to innovative approaches aimed at enhancing precision farming practices. Table 1 shows contributions from various researchers in the field of IoT based rover applications for smart farming.

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Objective of the Work	Methodology	Key Findings
Develop a Bluetooth controlled rover for soil monitoring [22]	Implemented sensors for soil moisture, temperature and pH. Used Bluetooth for remote control.	Improved precision in soil data collection and reduced manual labor.
Investigate the impact of IoT enabled rovers on crop yield [23]	Integrated rover with IoT sensors for monitoring soil conditions and crop health. Analyzed data over multiple growing seasons.	Demonstrated a positive correlation between IoT based rover interventions and increased crop yield.
Enhance rover capabilities for multi crop management [24]	Combined Bluetooth control with machine learning algorithms for crop identification. Tested on diverse crops.	Achieved accurate crop identification and adaptive rover actions for different crops.
Assess the energy efficiency of Bluetooth controlled rovers [25]	Implemented energy monitoring systems on rovers. Conducted field trials to measure energy consumption.	Identified energy efficient configurations for rover operations, contributing to sustainability.
Explore the scalability of IoT based rover networks [26]	Deployed multiple rovers in a networked configuration. Investigated communication protocols for scalability.	Demonstrated the feasibility of scaling up rover networks for large agricultural areas.

Table 1. Literature review table

Our proposed work uses a variety of sensors like soil moisture, DHT22 which are crucial for precision farming. The inclusion of GPS location monitoring enhances the contextual relevance of the data. GPS is also used to locate the rover location. Making the data accessible via a public channel on Thingspeak allows for convenient and widespread access. This aligns with the goal of providing real time information from anywhere. The inclusion of plots like Temperature versus Wind Speed and Histogram of Temperature Variations demonstrates an emphasis on visual data analysis. This provides actionable insights for precision farming on the same thingspeak channel.

Results and Discussions

The rover is controlled using Arduino Uno R3 Wi-fi, HC-05 Bluetooth module, DHT 22 sensor, Soil Moisture sensor. Figure 2 shows the top view of the smart farming rover. The rover is equipped with a variety of sensors to obtain real time data via the public channel on the Thingspeak cloud platform. As the channel is public, farmers and researchers have the ability to get location, humidity, soil moisture and

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temperature data at any moment from any place. This promotes an age of agricultural decision making that is based on data.

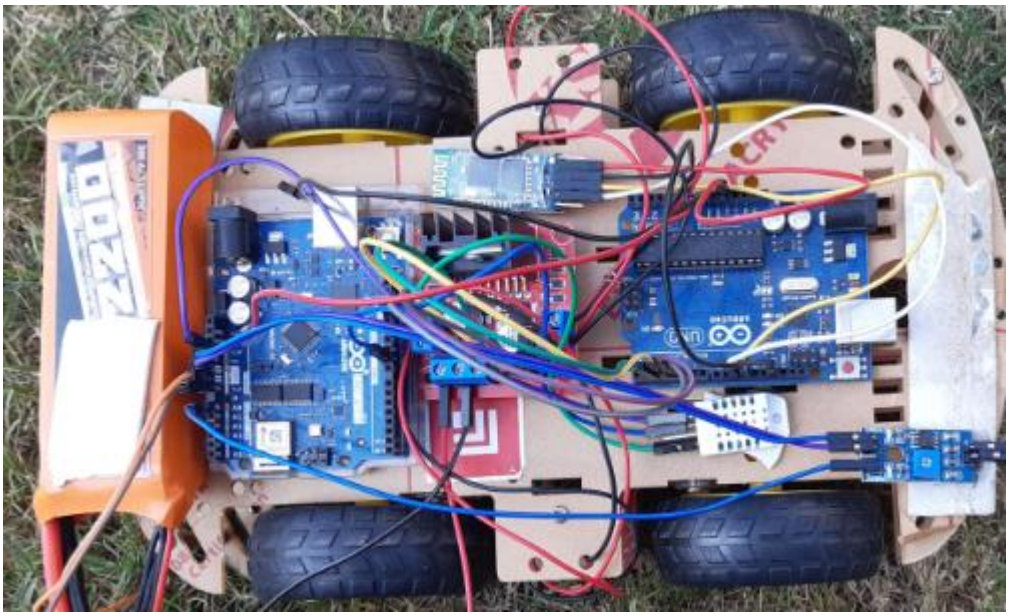


Figure 2. Top view of Smart farming rover

The main objective is to enhance precision farming by using IoT. The rover is controlled by Bluetooth module HC-05 via the mobile bluetooth. It not only delivers real time data but also allows for easy control via mobile devices. By using a wide range of sensors, farmers may get a thorough comprehension of the agricultural surroundings. This empowers them to make well informed choices regarding irrigation, crop well being and resource efficiency. Figure 3 shows the rover sensing soil moisture.

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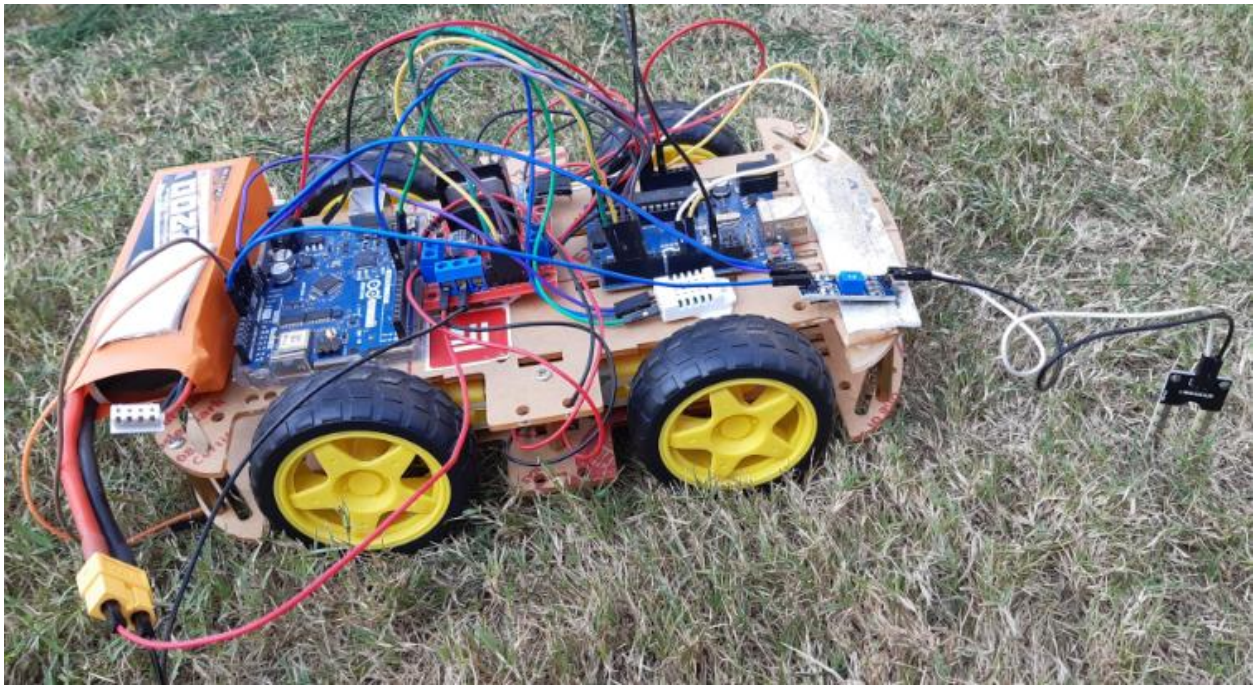


Figure 3. Sensing data and uploading on cloud

The data is uploaded to cloud platform Thingspeak though Campus Wifi. The publicly available data channel on Thingspeak facilitates collaborative information exchange among members of the agricultural community. This helps in cultivating a culture of openness and shared learning. Figure 4 shows details of the public channel created on MATLAB Thingspeak Platform. While figure 5 shows channel location. The location is taken through an integrated GPS sensor.



Figure 4. Screenshot of channel details on Thingspeak

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Figure 5. Rover location

A soil moisture plot allows farmers to monitor and understand the moisture content at different depths in the soil. This information is crucial for optimizing irrigation schedules. By observing trends in soil moisture levels over time, farmers can determine when and how much water is needed, preventing under or over irrigation. Overwatering can lead to waterlogging, adversely affecting root health and overall plant vigor. The soil moisture data is used for controlling the water motors and turning them according to the type of crop. Figure 6 shows a plot for soil moisture data.

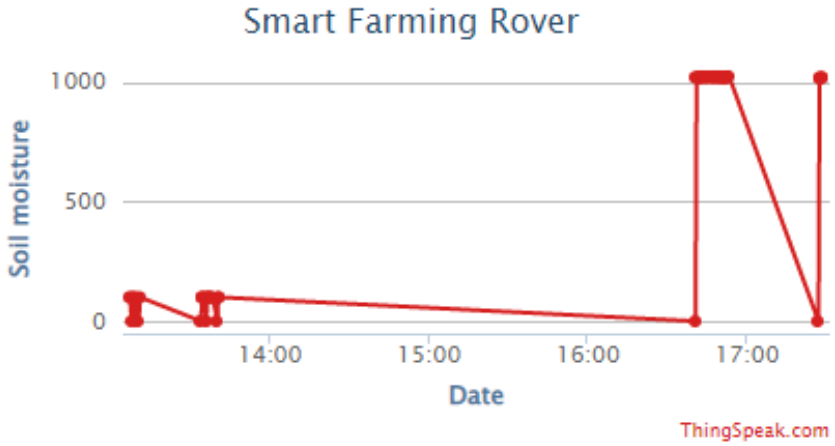


Figure 6. Plot of soil moisture data

Figure 7 Shows soil moisture data for one week. This plot can be used to check how many times the watering has been done and the ability of soil to retain water. This can be helpful for checking the condition of soil. Assessing soil condition is a critical aspect of farming as it significantly affects crop growth and yield.

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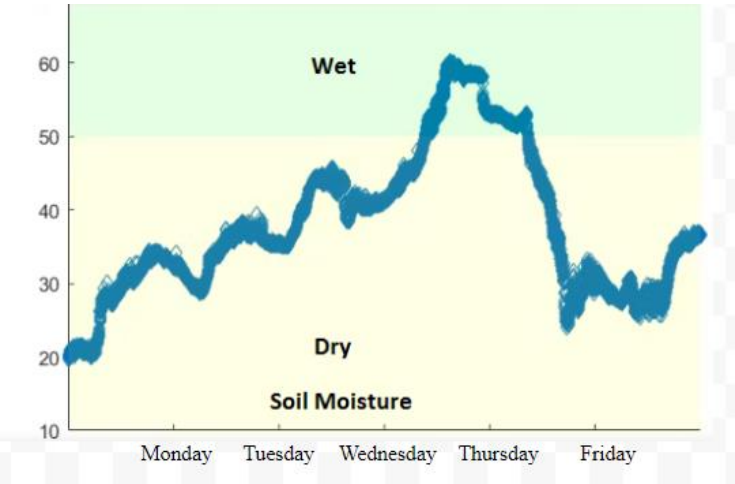


Figure 7. Soil Moisture data for one week

By examining the temperature and wind speed plot, farmers can assess the risk of frost or heat stress. Low temperatures combined with high wind speeds can lead to increased heat loss from plants, potentially causing frost damage. Such insights enable farmers to implement protective measures like covering crops during frost prone nights. Certain crops have temperature and wind speed preferences during their growth stages. Analyzing the plot allows farmers to identify ideal planting windows based on the crop requirements. Figure 8 shows the plot of temperature and wind speed. Temperature and wind speed can influence the effectiveness of pesticide applications. Some pesticides may evaporate quickly in high temperatures, while strong winds can disperse sprayed chemicals. The farmer can also check wind speed before watering the crops. If the wind speed is high, the automatic watering of crops may be postponed as it may damage or drop the crop.

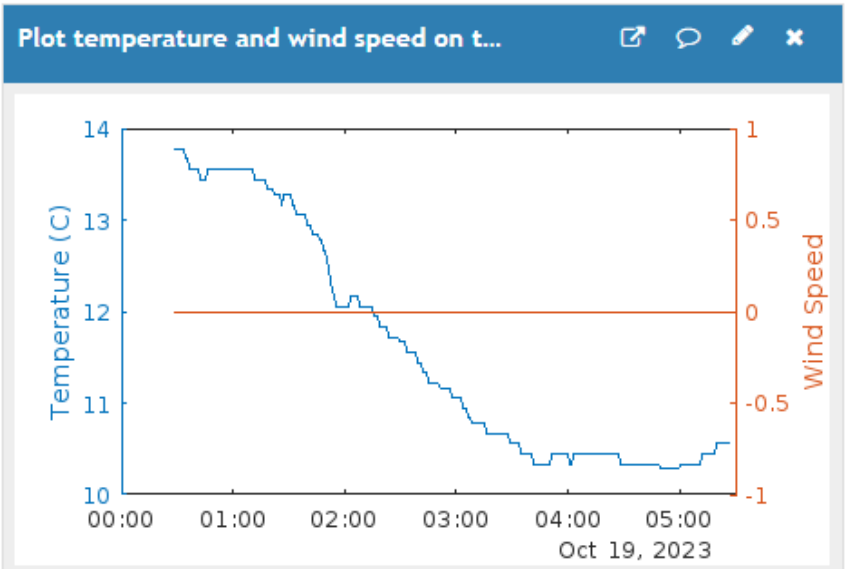


Figure 8. Temperature and wind speed data

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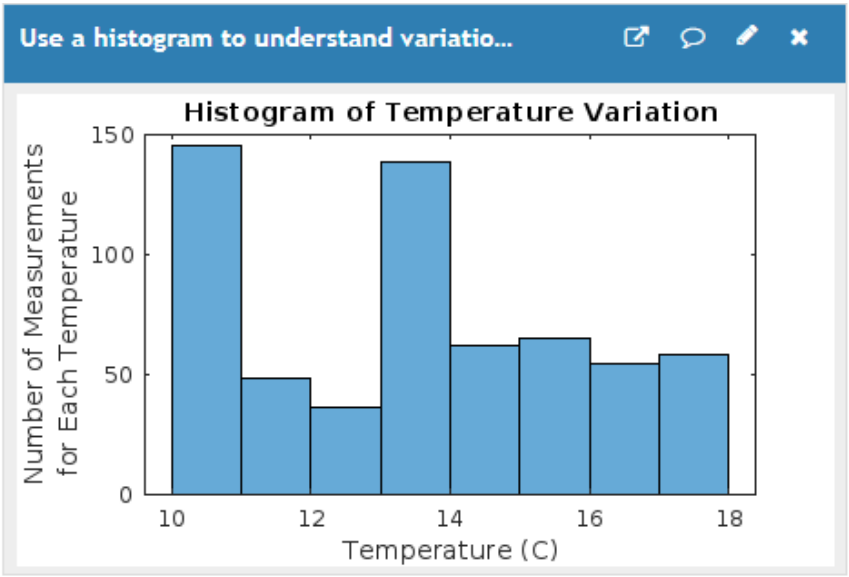


Figure 9. Histogram plot of temperature variation

Figure 9 shows histogram of temperature variation and samples taken for plotting histogram

A histogram allows farmers and agronomists to discern patterns in temperature variations over time. By analyzing the distribution of temperatures identification of recurring trends such as daily or seasonal temperature fluctuations can be identified. This understanding is crucial for making informed decisions about planting times, crop varieties and irrigation scheduling. By examining the temperature histogram, farmers can identify the optimal temperature ranges for specific crops. For example some crops thrive in warmer temperatures while others may prefer cooler conditions. Understanding the temperature distribution over time helps in selecting the most suitable times for planting, harvesting for maximizing crop yield and quality. Temperature variations influence soil moisture levels and evaporation rates. Analyzing the temperature histogram in conjunction with soil moisture data can help optimize irrigation strategies. Figure 10 shows the daily temperature variation plot.

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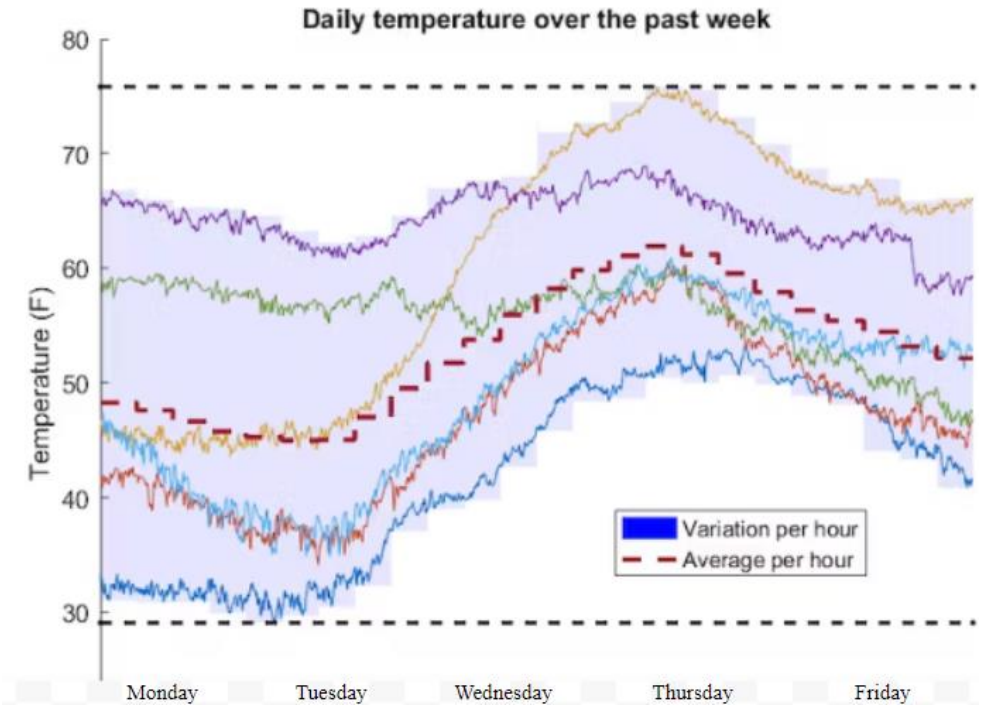


Figure 10. Daily Temperature variation plot

The public data on temperature variation, wind speed and soil moisture is essential for AI analysis and informed decision making. Temperature data aids in optimizing planting schedules and predicting frost risks, while wind speed insights enable efficient pesticide applications and soil erosion mitigation. Soil moisture data informs irrigation management, prevents over watering and enhances crop yield. By integrating these datasets, AI algorithms can provide actionable insights to optimize resource utilization, mitigate environmental risks, and improve overall farm efficiency and sustainability.

Conclusions

The Internet of Things based Bluetooth controlled rover shows the seamless integration of technology and agriculture, envisioning a future defined by sustainable and data driven precision agricultural methods. The rover is equipped with sensors that measure soil moisture, temperature, humidity and GPS. This allows for real time access to data and easy management via mobile devices. The use of the public channel on Thingspeak facilitates extensive accessibility to crucial agricultural data, promoting the adoption of a data centric methodology. The main objective of the project is to provide farmers with cutting edge technologies to make well informed decisions on irrigation, crop health and resource optimisation. The extensive array of sensors offers a thorough perspective on the agricultural surroundings. The data channel that is open to the public fosters cooperation among members of the agricultural community, hence increasing openness. Data visualization techniques, such as temperature vs. wind speed graphs and histograms, improve the understanding of climate processes. This data can be used for further AI analysis.

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SSA-optimized cascade optimal-FOPD controller for multi-area power system with RFB under deregulated environment

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Abstract

This study highlights a novel control strategy i.e., cascade optimal controller (COC)-fractional order proportional derivative (COC-FOPD is encouraged for improving AGC performance of deregulated power system (DPS) having the multi-area reheat thermal systems (RTS). The OC is acting as master controller and developed utilizing the full state feedback control (FSFC) methodology while FOPD performs the function of a secondary controller. Salp Swarm Algorithm (SSA), motivated by nature, is implemented for tuning the FOPD parameters. The performance of COC-FOPD controller has been compared with OC in two-area RTS. Further, the above system is amalgamated with redox flow battery (RFB) unit in both areas of the system and the impact of RFB in enhancing AGC performance is evaluated with proposed COC-FOPD compared to system without energy storage element. It has been revealed that COC-FOPD shown superior dynamic response as compared to OC. Further, a significant improvement in the system's dynamic performance is observed as a result of RFB incorporation.

Keywords

FOPD; optimal control (OC); RFB; SSA; cascade control scheme (CCS)

Introduction

To ensure reliability and flexibility to power delivery in altering system circumstances, the power sector is transitioning towards deregulated environment. It provide power to the consumer at a competitive price as the vertically integrated utility (VIU) is now interchanged by entities like generating companies (GENCOS), distribution companies (DISCOS) and independent service operator (ISO), in this restructured power system for exchange of electrical power, DISCOs can be configured to use any GENCO in a distinct pool or their own to full-fill their power demand. ISO, an impartial and self-regulating entity, implies safe and reliable power exchange operation. Among the many additional features it offers is frequency regulation, which is typically referred as AGC [1,2]. The AGC approach and system design may have an impact on system efficacy, a broad variety of conventional [2-5] and adaptive [6-16] approaches have been presented by the authors to adjust the controller parameters in DPS. Overseeing of nonlinear systems such as DPS makes controller gain optimization very challenging. The cascade control scheme (CCS), pioneered by Franks and Worley, and outperforms an elementary loop control system, particularly where it encounters disturbances. So, the cascade controllers (CC) are now extensively used and appreciated. As adjusting knobs increased in CC, according to the researchers it could be potentially more effective. To alleviate the AGC, the researchers have come up with a wide range of CC techniques which are superior compared to single loop control schemes in terms of both efficiency and

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efficiency [7-10, 13-16]. In conjunction with how effective controller designs enhance AGC performance in DPS, the utilization of an energy storage (ES) element has now increased and shown a remarkable improvement. Various researchers incorporated RFB with AGC and shows better dynamic performance by providing power consistently to load while preserving a little system cost [4-5, 7, 11, 15-16]. As CCS perform better than single loop strategies we are proposing a new COC-FOPD control strategy for two-area RTS operating in deregulated market environments. The above technique uses OC as the primary/master controller, and optimal control theory (OCT) is utilized for determining the controller's optimal FGM (K), however SSA has been adopted for determining the optimum gains of the secondary/slave FOPD controller. To validate the superiority of the COC-FOPD controller the system dynamic responses has been compared to OC when simulated in similar environment. Finally, to explore the way RFB contributes to dynamic performance improvement one RFB in each area has been integrated with COC-FOPD for the examined power systems.

System model

Each area of RTS has two DISCOs and two similar reheat thermal generating units. Fig. 1 implies a transfer function model (TFM) of the RTS which comprises RFB unit in both areas. Two reheaters, two thermal turbines, two speed governors and combined load demand from DISCOs are featured in each region of the two-area RTS. Version 9.0.0 (2016a) of the software program MATLAB was used for obtaining the system dynamic results. Symbols in Fig. 1 are designated adopting exactly the same nomenclature utilized in [2, 16].

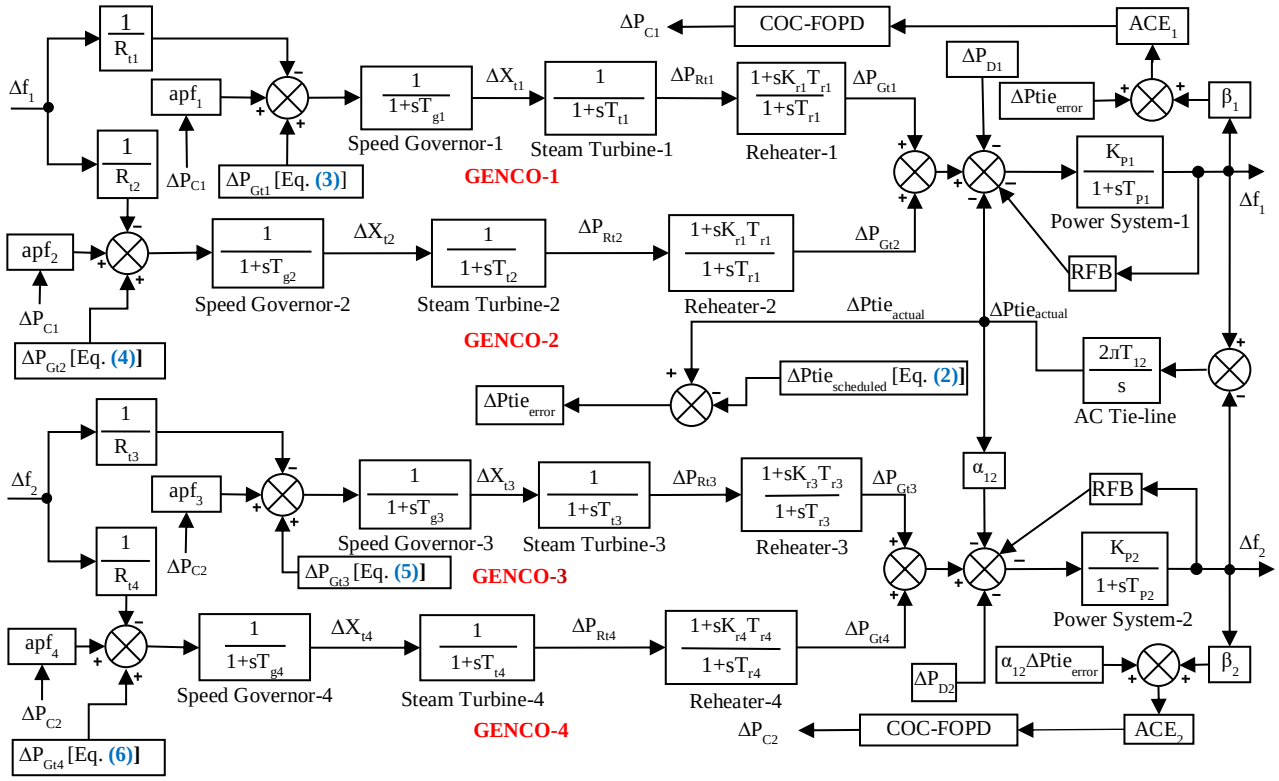


Fig. 1. TFM block diagram (BD) of two-area RTS incorporated with one RFB in each area [2]

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Design of the cascade controller

For AGC purposes, CCS comprises two control loops: one controller's feedback loop nuzzling the second controller's feedback loop, and the primary controller's control output providing as the second controller's set point, that's the reason this provide a robust response to perturbations.. FGM known as matrix K which always utilized to design control signal is obtained using OCT and for RTS it is provided in table 1 [2] and for the same system with RFB in both area has been provided in table 2 [16]. The BD of proposed COC-FOPD controller and secondary FOPD has been provided in fig 2(a) and 2(b) respectively. Utilizing SSA, the optimal gain for the secondary FOPD controller has been obtained. Details on SSA, including their distinctive characteristics, algorithm and mathematical modelling can be found in the [16-17]. Integration of time square of error (ITSE) has been utilized as cost function for this work.

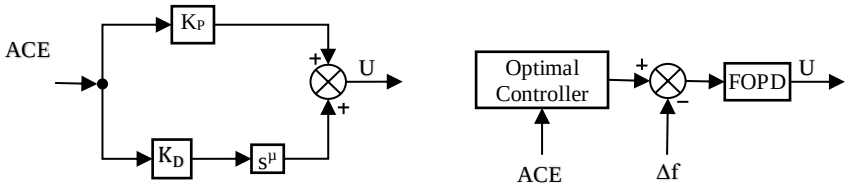


Fig. 2. Block diagrams of (a) FOPD controller, (b) proposed COC-FOPD controller.

Results and Discussion

The RTS with case-1 in [2] inter linked via an AC tie-line under deregulated environment is considered. The different DISCOs' electric power requirements are $\Delta P_{L1} = 0.01$ puMW, $\Delta P_{L2} = 0.01$ puMW, $\Delta P_{L3} = \Delta P_{L4} = 0$ puMW and $\Delta P_{UC1} = \Delta P_{UC2} = 0$ puMW. Here is the related disco participation matrix (DPM):

$$\text{DPM} = \begin{bmatrix} 0..5 & 0 & 0.5 & 0.1 \\ 0 & 0.5 & 0 & 0.4 \\ 0.5 & 0.5 & 0..5 & 0 \\ 0 & 0 & 0 & 0.5 \end{bmatrix} \quad (1)$$

The data show that all four GENCOs have participated in AGC as $apf_1 = apf_2 = apf_3 = apf_4 = 0.5$. The Eqs. for $\Delta Ptie_{scheduled}$ and steady state power generation will be given as:

$$\Delta Ptie_{scheduled} = (cpf_{13}+cpf_{23})\,\Delta P_{L3} + (cpf_{14}+cpf_{24})\,\Delta P_{L4} - (cpf_{31}+cpf_{41})\,\Delta P_{L1} - (cpf_{32}+cpf_{42})\,\Delta P_{L2} \quad (2)$$

$$\Delta P_{Gt1} = cpf_{11}\,\Delta P_{L1} + cpf_{12}\,\Delta P_{L2} + cpf_{13}\,\Delta P_{L3} + cpf_{14}\,\Delta P_{L4} \quad (3)$$

$$\Delta P_{Gt2} = cpf_{21}\,\Delta P_{L1} + cpf_{22}\,\Delta P_{L2} + cpf_{23}\,\Delta P_{L3} + cpf_{24}\,\Delta P_{L4} \quad (4)$$

$$\Delta P_{Gt3} = cpf_{31}\,\Delta P_{L1} + cpf_{32}\,\Delta P_{L2} + cpf_{33}\,\Delta P_{L3} + cpf_{34}\,\Delta P_{L4} \quad (5)$$

$$\Delta P_{Gt4} = cpf_{41}\,\Delta P_{L1} + cpf_{42}\,\Delta P_{L2} + cpf_{43}\,\Delta P_{L3} + cpf_{44}\,\Delta P_{L4} \quad (6)$$

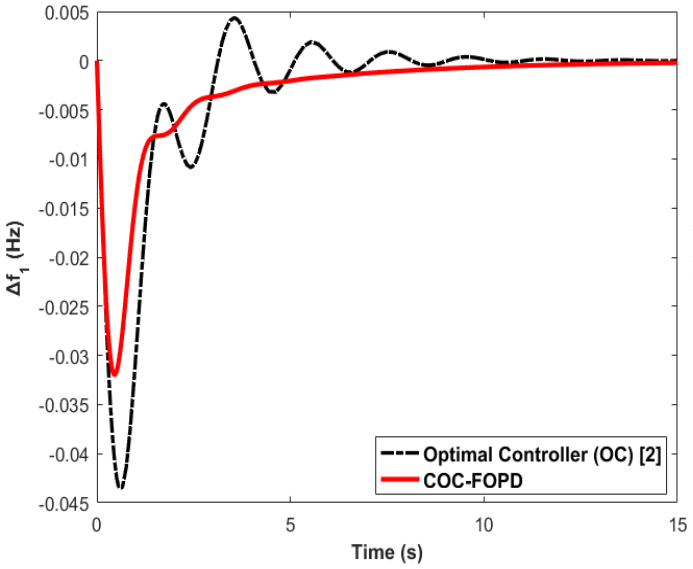
Considering Eqs. (2)-(6), It is urged that GENCOs deliver steady-state powers as $\Delta P_{Gt1} = 0.005$, $\Delta P_{Gt2} = 0.005$ puMW, $\Delta P_{Gt3} = 0.01$, $\Delta P_{Gt4} = 0$ puMW and $\Delta Ptie_{scheduled} = -0.01$ puMW. For the simulation of system COC-FOPD has been deployed. The optimized FGM (K) for OC has been obtained from [2] as shown in Table 1. The optimized gain for FOPD controller has been calculated through the employing of SSA and is demonstrated in Table 3 for COC-FOPD. The critical analysis of maximum overshoot, maximum undershoot, for variation in area frequencies (Δf_1 and Δf_2) [Figs. 3(a)-(b)] and deviation in tie-line error power ($\Delta Ptie_{error}$) [Fig. 3(c)] for RTS with various controller COC-FOPD has lower value for both parameter compared to OC. Critical analysis show that for OC it has shorter rise time but longer oscillation. However, the COC-FOPD control approach offers an excellent balancing by providing controlled oscillation, comparable rising time

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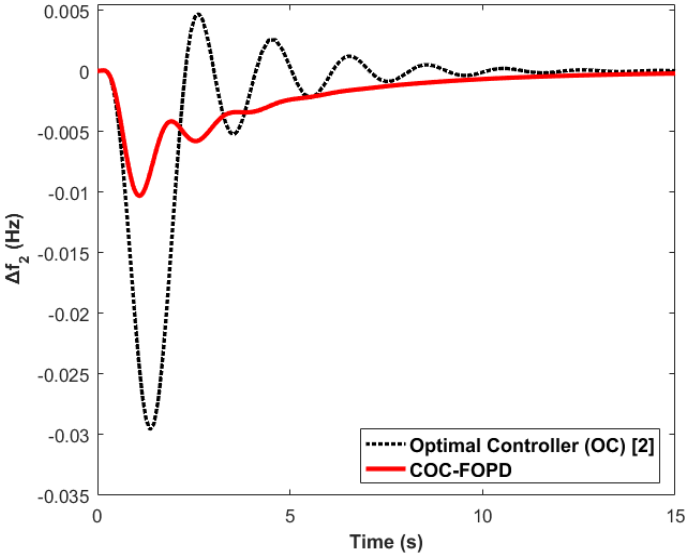
values, and reduced undershoot and overshoot values. Critically analysis of $\Delta f_1/\Delta f_2$ [Figs. 3(a)-(b)], $\Delta Ptie_{actual}/\Delta Ptie_{error}$ [Fig. 3(c)] and a change of GENCOs' power generation (ΔP_{Gt1}, ΔP_{Gt3} and ΔP_{Gt4}) [Figs. 3(d)-(f)] depicts that the SSA-tuned COC-FOPD controller performs more effectively compared to the OC [2].

Table 1.
Optimal FGM (K) for restructured two-area RTS [2].

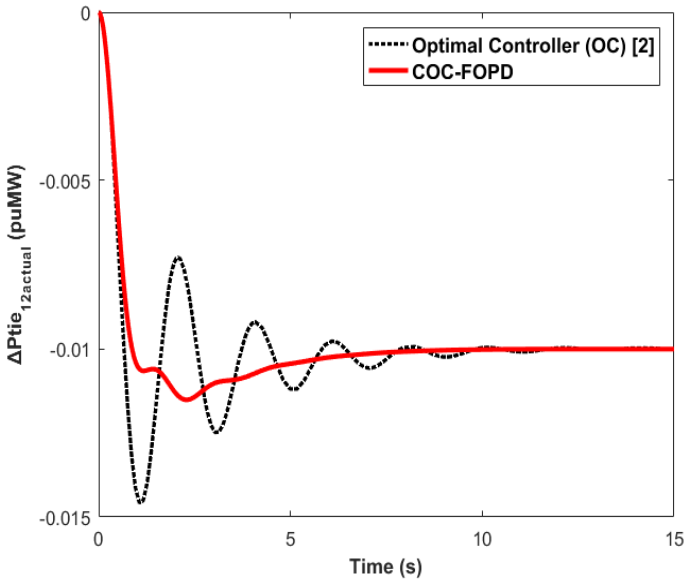
[0.2940	0.0208	2.3847	–0.4330	0.0732	2.1972	–0.4264	0.0598	–0.0228
0.0030	–0.0015	–0.0228	0.0030	–0.0015	–0.2712	1.0000	–0.0082;	
–0.0191	0.2809	–0.0051	0.0032	0.0016	–0.0807	0.0059	–0.0047	2.1503
–0.4130	0.0601	2.1503	–0.4130	0.0601	0.3736	0.0082	1.0000]	



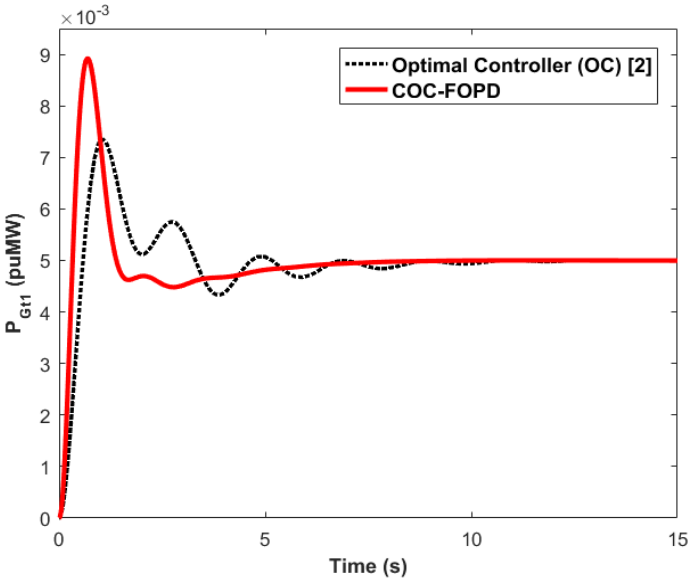
(a)



(b)

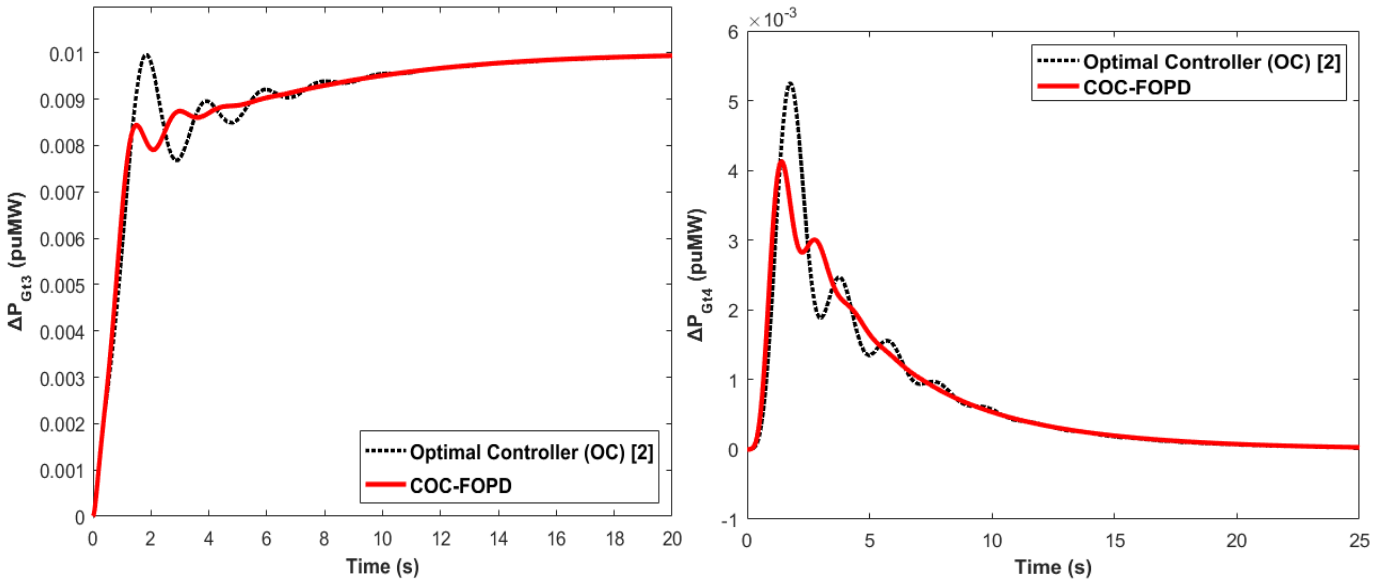


(c)



(d)

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(e) **(f)**

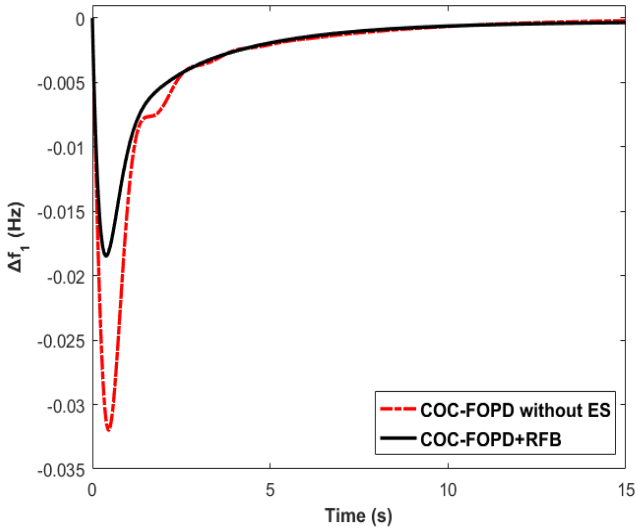
Fig. 3. Dynamic responses of two-area restructured RTS with the purposed cascade approach compared to OC: (a) Δf_1, (b) Δf_2, (c) $\Delta Ptie_{actual}$, (d) ΔP_{Gt1}, (e) ΔP_{Gt3} and (f) ΔP_{Gt4}.

Table 2. Optimal FGM K for restructured two-area RTS with RFB [16].								
[0.0294	–0.0403	2.0076	–0.2887	0.2912	2.0076	–0.2887	0.2912	–0.3204
0.0675	–0.0059	–0.3204	0.0675	–0.0059	0.3914	1.0000	–0.0000	–0.0000
0.0000;								
–0.0403,	0.0294,	–0.3204,	0.0675,	–0.0059,	–0.3204,	0.0675,	–0.0059,	2.0076,
–0.2887,	0.2912,	2.0076,	–0.2887,	0.2912,	–0.3914,	0.0000,	1.0000,	0.0000,
–0.0000]								

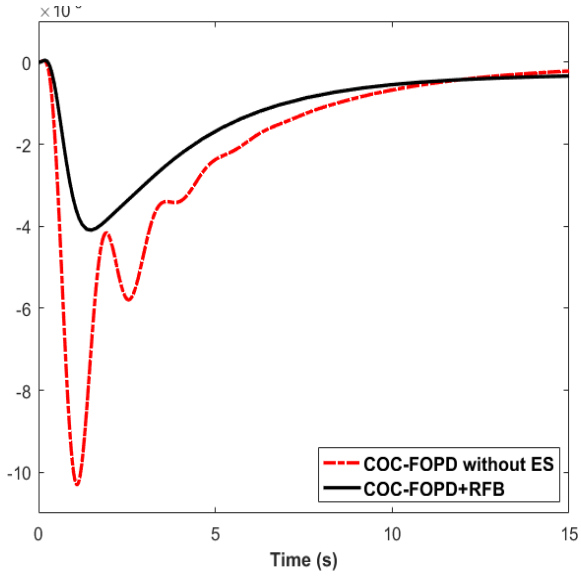
Comparison of system performance in presence of RFB

The system with case-1 in [2] is considered and one RFB in each control area has been incorporated and primary controller i.e. OC has been redesigned. In order to achieve this, the FGM for the RTS has been revised by include two additional RFB states, one for each area and presented in Table 2 [16]. To compare the effectiveness of ES, dynamic response for AGC of RTS with proposed cascade controller in absence and presence of RFB has been compared and showcased in Fig. 4. The corresponding convergence curves have been shown in Fig. 4(h). When RFB is coupled with COC-FOPD for AGC purposes, the dynamic performance is enhanced by further reducing or suppressing oscillation and peak overshoot/undershoot as compared to same COC-FOPD controller in absence of any ES. GENCOs power output is steady and matches the scheduled value in steady state [Figs. 4(d)-(g)]. In case of COC-FOPD integrated with RFB it returned with a lower value of cost function (ITSE) which is evident from both the convergence curve [Figs 4(h)] and Table 3

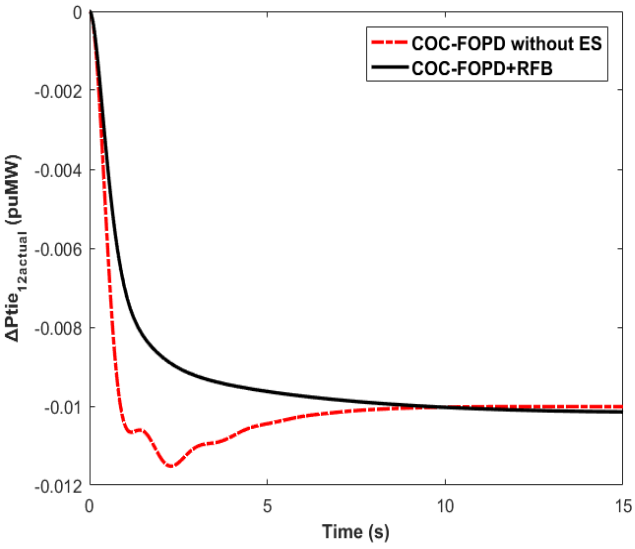
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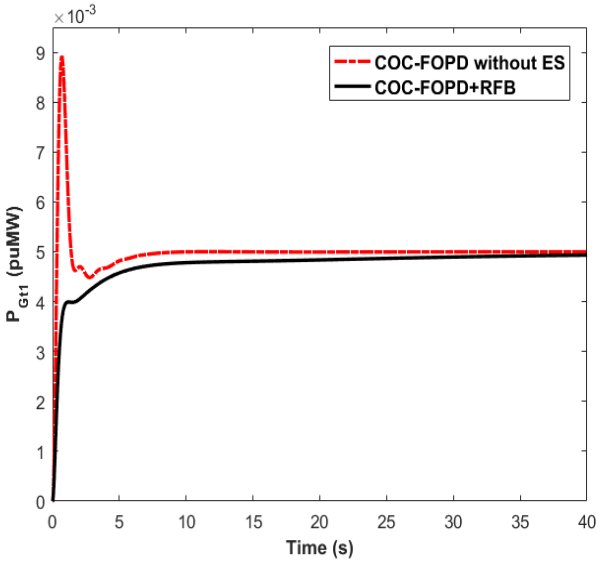
(a)



(b)



(c)



(d)

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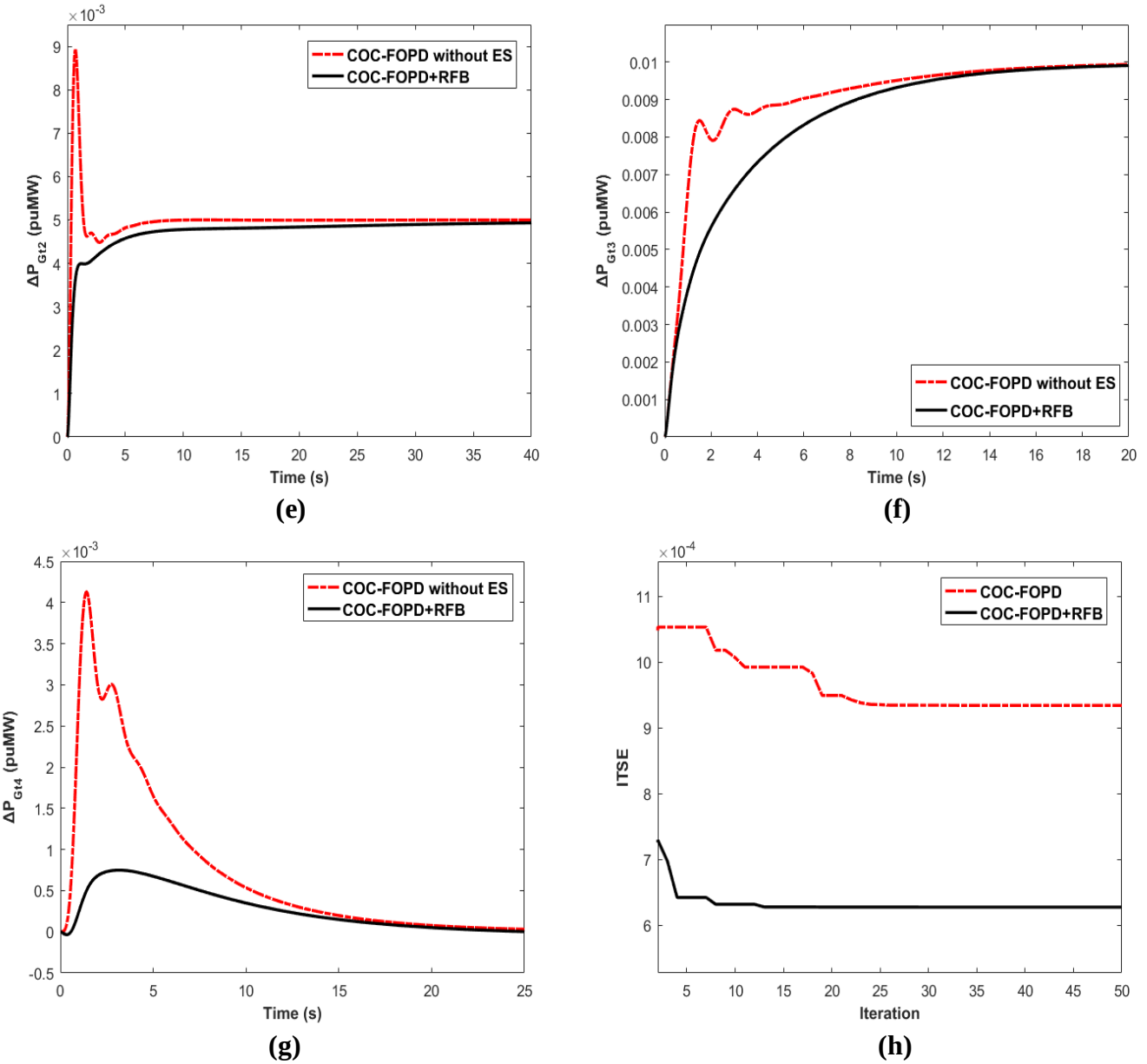


Fig. 4. Dynamic responses of two-area restructured RTS with the purposed cascade approach in presence and absence of RFB: (a) Δf_1, (b) Δf_2, (c) $\Delta Ptie_{actual}$, (d) ΔP_{Gt1}, (e) ΔP_{Gt2} (f) ΔP_{Gt3} (g) ΔP_{Gt4} and (h) convergence curve

Table 3.
Optimal parameters and ITSE value for COC-FOPD /COC-FOPD+RFB for RTS

Parameters	OC	COC-FOPD	COC-FOPD+RFB
ITSE	0.0169000	0.00093429	0.00062763
K_{P1}	-	0.064406	0.1
K_{D1}	-	1.1797	0.1
µ1	-	0.34738	0.91158
K_{P2}	-	0.848	0.1

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K_{D2}	-	0.75547	0.1
µ2	-	0.044174	0.73751

Conclusion

- A novel COC-FOPD has proposed and explored in a deregulated setting with the objective of improving the AGC performances of two-area RTS.
- The FSFC technique, which is based on the performance index minimization criterion, was used to create the process's primary controller. The gains of the FOPD controller are then adjusted by exhausting SSA.
- Simulation results establish that the COC-FOPD controller deliver improved dynamic performance compared to OC two-area RTS when simulated in similar environment.
- Furthermore, positive impact of redox flow battery (RFB) is examined on the DPS performance with COC-FOPD controller When RFB incorporated with COC-FOPD the system demonstrates substantially enhanced performance in terms of lesser peak deviations and lesser magnitude/number of oscillations.

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STATE ESTIMATION BASED KALMAN FILTER FOR SOC PREDICTION OF LI-ION BATTERY

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Abstract

Battery-based energy storage is commonly used in the present-day scenario in many devices like electrical vehicles, smart grids, laptops, and IoT handheld devices. The State of Charge (SOC) parameter is a crucial performance indicator for optimizing battery utilization and enhancing its overall life cycle. However, it is not possible to calculate the SOC directly as it depends on the battery open circuit voltage, age of the battery, and temperature factors. SOC can be estimated using Kalman filter-based state estimation algorithms, which can be part of intelligent BMS (Battery Management Systems). In this paper, Kalman filter based method is used for estimating SOC of lithium-ion batteries estimated by Kalman filter is reached closed to true SOC after 10,000 iterations. However, this method needs higher iteration for more accurate prediction and iteration of SOC depends on the battery model. If the model is complicated then it gives a battery estimation, but the implementation of an algorithm is difficult.

Keywords

State of Charge, Kalman Filter, Battery Model, Battery Management System (BMS)

Introduction

Battery-based energy storage devices are an indispensable component of modern life, whose profound usage can be seen in multiple devices like computers, tablets, and smartphones [1]. As an alarming increase in urban pollution caused by the tail-pipe emission of IC (Internal Combustion) engine-based vehicles and the increase in the volatility of the price surge in petrol and diesel resources, EVs are receiving significant interest as a means of environment-friendly and sustainable transportation mode [2]. EVs make use of the stored electrochemical energy in the battery and different battery chemistries like NiMH, lithium-ion batteries, and lead-acid batteries are commonly used in EVs as discussed.

The increasing popularity of lithium-ion batteries in Electric Vehicle (EV) applications is attributed to their high energy density, excellent efficiency, and extended lifespan. The battery

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is being considered as the crucial and expensive component of the EV [3][4]. The SOC of the battery is the level of a charged electric battery relative to its capacity. Accurate SOC estimation with smart and intelligent BMS is essential for the safe and effective operation of EV batteries, which includes the protection circuitries to prevent the damage associated with short circuits, overcharging, and over-discharging of the batteries and cell balancing in large battery packs. In this paper, we calculate the SOC of a lithium-ion battery. SOC is not measured directly just like a terminal voltage and temperature. Fig.1. describes the basic block of SOC estimation using the Kalman filter.



Fig.1 Basic block diagram for soc estimation

Rest of the paper is as follows; section-II describes Battery Management System. Section -III describes battery model; Battery Model is stated in section IV. Section V discusses battery model and Kalman filter and Section VI thus concludes this paper.

Battery management system

BMS is a circuit that is used to maintain, protect, and control batteries [5][6]. BMS consists of various peripheral devices for receiving inputs/outputs and feedback. the primary focus of BMS for safety and reliable battery operation. BMS collects real-time data like voltage, current, and temperature of the battery pack. Algorithms and embedded in it to estimate the battery's various parameters like state of charge, state of health, remaining useful life, and others, etc. This estimated data is used for various operations like cell balancing, estimating the life cycle of the battery, thermal protection, overcharging protection, and undercharging protection. In this paper, we estimate SOC with the help of a state estimation algorithm using Kalman filters [7-9].

The Battery Management System (BMS) is an essential circuit utilised to uphold, safeguard, and regulate batteries [10]. Composed of diverse peripheral devices for input/output reception and feedback, the primary objective of BMS is to ensure the safety and reliability of battery operations. Real-time data, including voltage, current, and temperature of the battery pack, is collected by the BMS.Embedded within the BMS are algorithms designed to estimate various battery parameters, such as state of charge (SOC), state of health (SOH), remaining useful life, among others [11-13]. These estimations play a crucial role in operations such as cell balancing, determining the battery's life cycle, and providing thermal, overcharging, and undercharging protections. In this study, our focus lies on the estimation of SOC utilising a state estimation algorithm, employing Kalman filters. By leveraging the capabilities of Kalman

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filters, we aim to accurately assess the SOC of the battery in real time, thereby enhancing the efficiency and reliability of battery management systems. In batteries, SOC is always a challenging task to measure. The State of Charge (SOC) serves as a valuable metric, offering insights into the remaining useful life and overall reliability of the battery. SOC also provides additional information on charging and discharging strategies. This information is essential for our application. SOC depends on temperature, age, and current. The SOC is established by comparing the available current capacity to the nominal capacity, represented as a percentage.

$$\square\square\square(t) = SOC(0) - \int \frac{\square\square\square}{\square\square} \quad (1)$$

In the given context, where:

- *SOC(t)* means SOC at a particular time t seconds.
- *SOC (0)* means SOC at a time t-1 seconds.
- *i* represents battery current,
- C_n denotes nominal capacity, and *dt* stands for change in time.

As the SOC cannot be measured directly, state estimation based Kalman filter is used to estimate the SOC.

Battery Model

Understanding the battery chemistry and physics-based modelling is a good approach but for analysis purposes, we convert the battery model to an equivalent electrical model. The equivalent circuit model consists of a DC voltage source, resistance, and capacitance elements to represent the electrical characteristics of the battery [14][15].

In Fig.2 the provided information:

- R0 signifies the internal resistance of the battery,
- OCV(z(t)) represents the dependent voltage source
- R1C1 stands for the diffusion voltage

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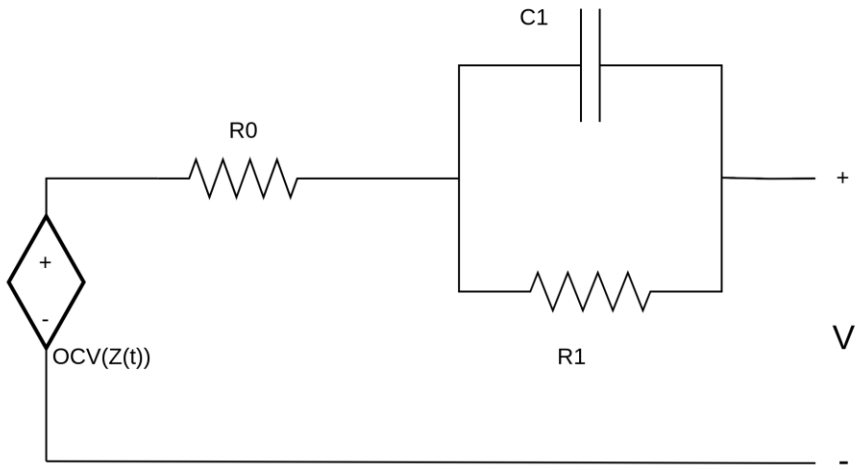


Fig.2 Equivalent battery model

Models' equation.

$$\square_{\square+1} = \square_{\square} - \frac{\Delta\square}{\square} \square \square_{\square} \quad (1)$$

$$\square_{\square,\square+1} = \square\square\square . (\frac{-\Delta\square}{\square 1 \square 1}) \square_{\square,\square} + (1 - \square\square\square(-\frac{\Delta\square}{\square 1 \square 1})) \square_{\square} \quad (2)$$

The initial equation describes the dynamics of State of Charge (SOC), with Q denoting the nominal capacity of the battery and Δt representing the discrete time step [7]. One R1C1 parallel circuit is use for the dynamic response of battery response and $\square = \square 1 \square 1$ is the time constant for RC circuit. Z_{K+1}

State space model vector representation matrix form.

$$\begin{bmatrix} Z_{K+1} & 0 \\ i_{R,K+1} & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & \exp(-\frac{\Delta t}{R1C1}) \end{bmatrix} \begin{bmatrix} Z_K & 0 \\ I_{R,K} & 0 \end{bmatrix} + \begin{bmatrix} 0 & \frac{\Delta t}{Q} \\ 1 & 1 - \exp(-\frac{\Delta t}{R1C1}) \end{bmatrix} i_k$$

In this equation, A and B represent

$$A = \begin{bmatrix} 1 & 0 \\ 0 & \exp(-\frac{\Delta t}{R1C1}) \end{bmatrix}$$

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$$B = \begin{bmatrix} 0 & \frac{-\Delta t}{Q} \\ 0 & 1 - \exp(-\frac{\Delta t}{R1C1}) \end{bmatrix}$$

The output equation 3 and 4 of the model articulates the relationship among cell voltage, current, and SOC.

$$V_k = OCV(Z_k) + \Sigma R_i\, i_{R_i,k} - R_0\, i_k \quad (3)$$

$$V_k = OCV(Z_k) + \square\, x_k + Di_k \quad (4)$$

Value of C and D

$$C = [0, -R1],\ D = [-R0]$$

State space equation of this model.

$$x_{k+1} = A_k x_k + B_k i_k \quad (5)$$

$$Y_k = C_k x_k + D_k i_k \quad (6)$$

Here x_{k+1} and Y_k in state space equation represent input and output, respectively.

Kalman filter algorithm

The block diagram depicted in Fig. 3 illustrates the Kalman filter algorithm's two primary steps prediction and correction [16-18]. All these steps are executed using MATLAB script. The block diagram provides detailed insights into the implementation of the Kalman filter algorithm.

The first step of determining SOC estimation by using Kalman filter algorithm. We constructed a battery model based on relevant literature. utilizing current as input and voltage as output. Current values are derived from our battery model and compared with the actual current of the battery. During the prediction step of the algorithm, we assess the output voltage from the

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battery model and actual voltage of battery. In this step, we compare the voltage from the battery model with the actual battery voltage and calculate the Kalman gain. Utilizing this Kalman gain, we refine the correction step of the algorithm to estimate the SOC. This estimated SOC is then compared with the actual SOC obtained from the real battery. Through this comparison, we validated the accuracy of our results. detailed explanation of Kalman filter algorithm is discussed below [19][20].

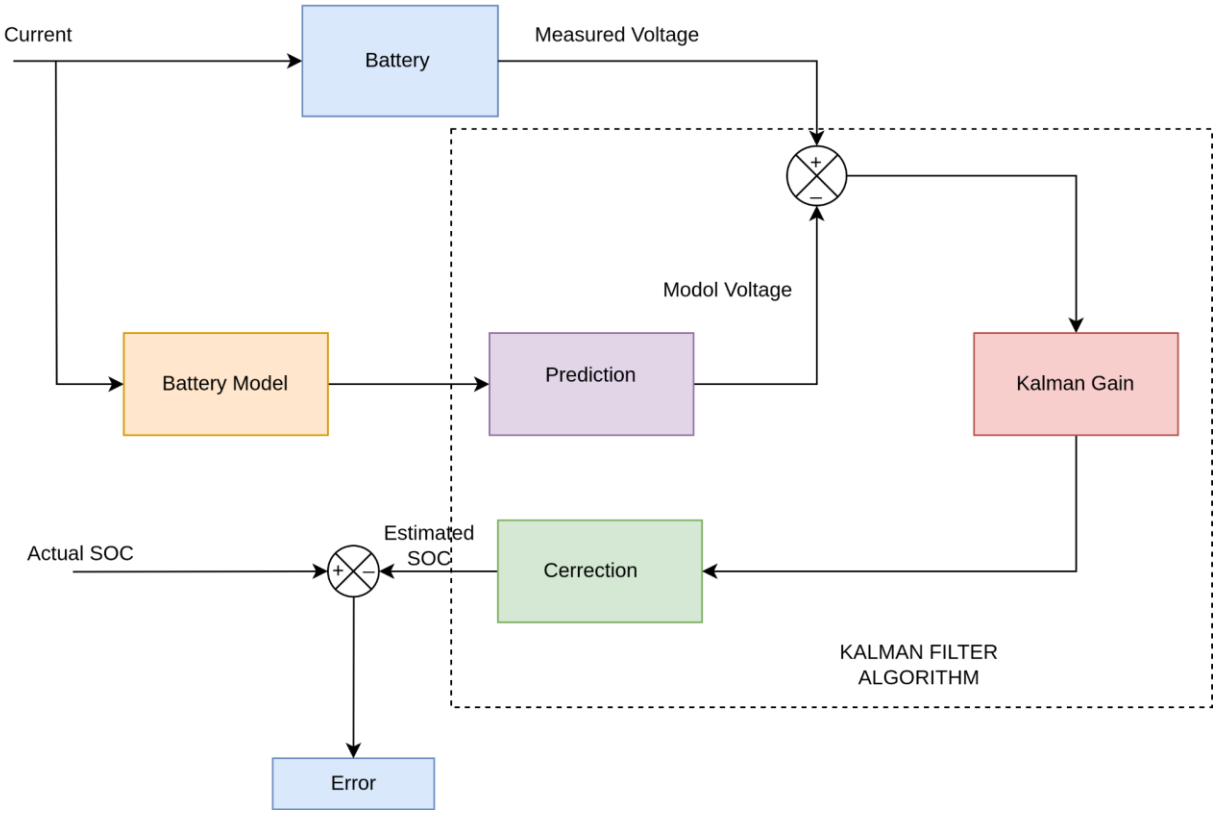


Fig.3 Detail block diagram of Kalman filter base algorithm for SOC estimation

$$x_{k+1} = A_k x_k + B_k i_k + w_k \quad (7)$$

$$Y_k = C_k x_k + D_k i_k + v_k \quad (8)$$

□□ and □□ is random noise for experimental purpose.

Prediction:

a) State prediction time update: This step involves projecting the current state estimate

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forward in time using the system dynamics model. It predicts the state of the system at the next time step without considering new measurements. The predicted state serves as the basis for the subsequent correction step. Mathematically, it can be expressed as:

$$\widehat{x_k} = E[x_k, Y_{k-1}] = E[f(x_{k-1}, u_{k-1}, w_{k-1}), Y_{k-1}] \quad (9)$$

With the given past measurements, the present state is predicted in this step. With the most recently estimated state and by using the system model, the mean is propagated forward in time.

b) Error covariance time update: After predicting the state, we need to update the covariance matrix associated with the state estimate. This matrix represents the uncertainty in the predicted state. The prediction is affected by uncertainty in both the current state estimate and the system dynamics. This step ensures that the uncertainty is appropriately propagated forward in time. Mathematically, it can be expressed as

$$\Sigma^{-}_{\hat{x},k} = E[(x_k - \widehat{x_k})(x_k - \widehat{x_k})^T] \quad (10)$$

When estimating error covariance of the state prediction, the best we can do is to use the most recent covariance estimate and propagate it forward in time.

c) Predict system output: The predicted system output provides an estimate of what the measurements of the system are expected to be at the next time step, based on the predicted state of the system and the observation matrix.
This prediction can be used for various purposes, such as control, monitoring, or decision-making, depending on the specific application of the Kalman Filter.

$$\widehat{y_k} = E[y_k, Y_{k-1}] = E[h(x_k, u_k, w_k), Y_{k-1}] \quad (11)$$

Correction:

a) Estimator gain matrix**:** The Kalman Gain matrix, denoted as , □□determines the balance between the prediction and the measurement during the correction step of the Kalman Filter algorithm. It is crucial to determine how much weight to assign to the new measurement compared to the prediction.
The Kalman Gain matrix is calculated as

$$L_k = \Sigma^{-}_{x\hat{y},k} \; \Sigma^{-1}_{\hat{y},k} \quad (12)$$

b) State estimate measurement update: This term refers to the process of updating the predicted state estimate based on the new measurement information. The predicted state estimate is adjusted towards the actual measurement by an amount determined by the Kalman Gain.
Mathematically represented as,

$$\hat{x}^{+}_k = \hat{x}^{-}_k + L_k(y_k - \widehat{y_k}) \quad (13)$$

c) Covariance estimate measurement update: This term refers to the update of the covariance matrix associated with the state estimate based on the new measurement information. It represents the uncertainty in the state estimate after incorporating the measurement.

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Mathematically represented as,

$$\Sigma^{+}_{\hat{x},k} = \Sigma^{-}_{\hat{x},k} + L_k \, \Sigma_{\hat{y},k} L_k^T \quad (14)$$

Results

The implementation of the Kalman filter algorithm is facilitated through the utilization of a MATLAB script. The outcomes derived from employing a single RC battery model have been meticulously documented. The effectiveness of the Kalman filter algorithm has been scrutinized across four distinct conditions.

The resultant data are comprehensively depicted in Figures 4, 5, and 6. Within these figures, the genuine SOC values are denoted by blue dotted lines, serving as a reference point. Meanwhile, the estimated SOC values generated by our model are represented by solid black lines.

The Fig.4(a),5(a),6(a) horizontal X-axis delineates the number of iterations undertaken during the algorithm's execution, while the vertical Y-axis illustrates the SOC state, which spans the range from 0 to 1. These visualizations offer a clear insight into the performance of the Kalman filter algorithm under various conditions, enabling a thorough assessment of its accuracy and reliability in estimating the State of Charge across different scenarios. In Fig.4(b),5(b),6(b) represents the error range.

a) When the true value and initial value are both at the same point, the result shows that a smaller number of iterations are required.

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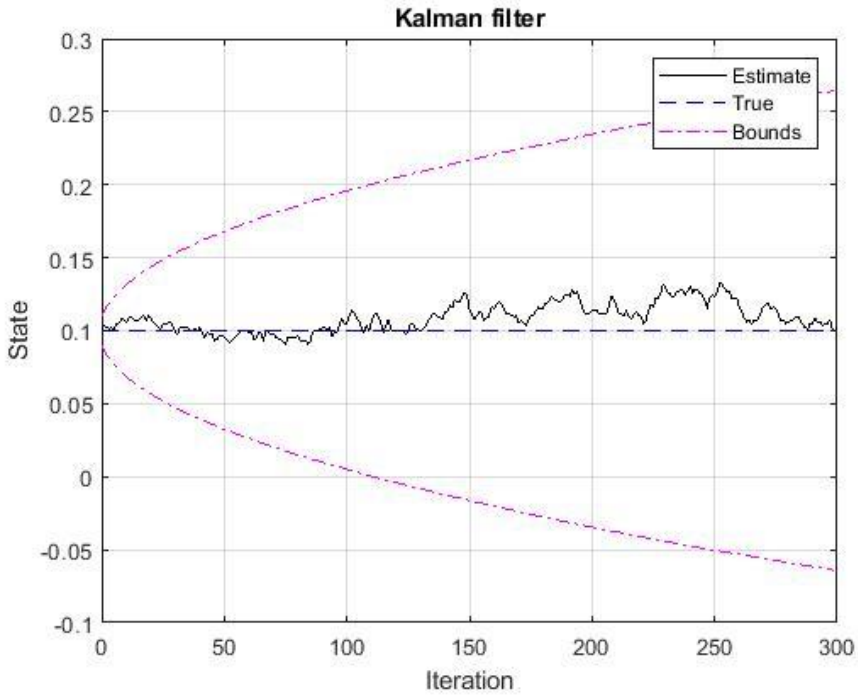


Fig.4(a) SOC prediction while adding Random Noise.

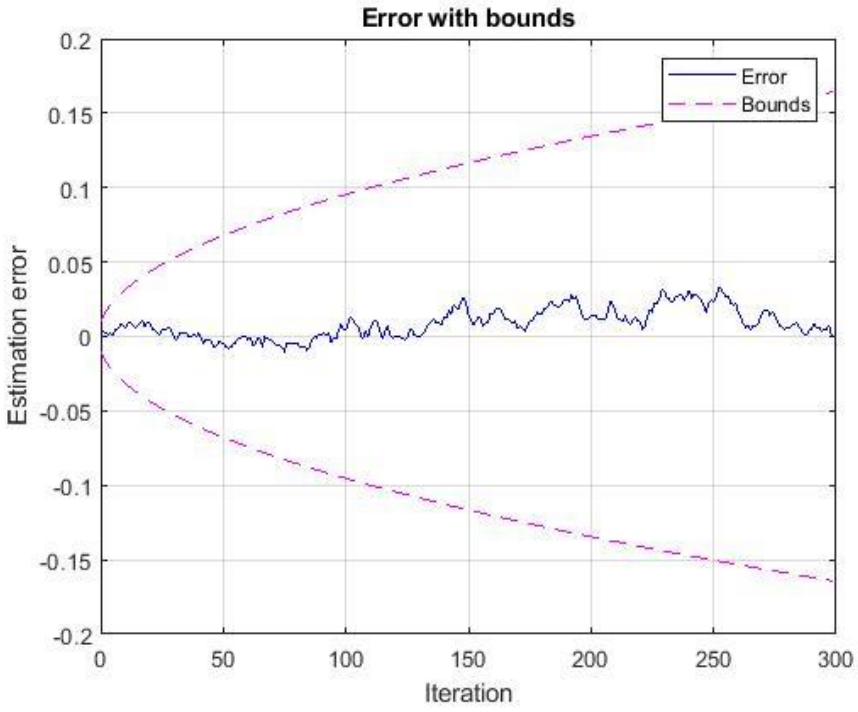


Fig.4(b) Error remains less than 0.05 in this case

b) When the true value and initial value at with small difference then the result shows the number of iterations increases.

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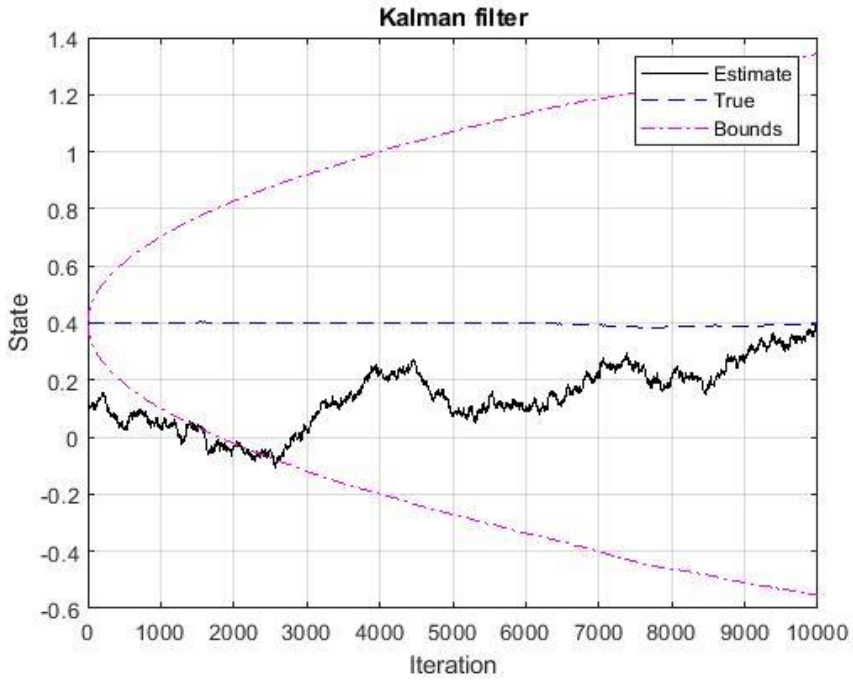


Fig 5(a) SOC prediction after 10000 iterations.

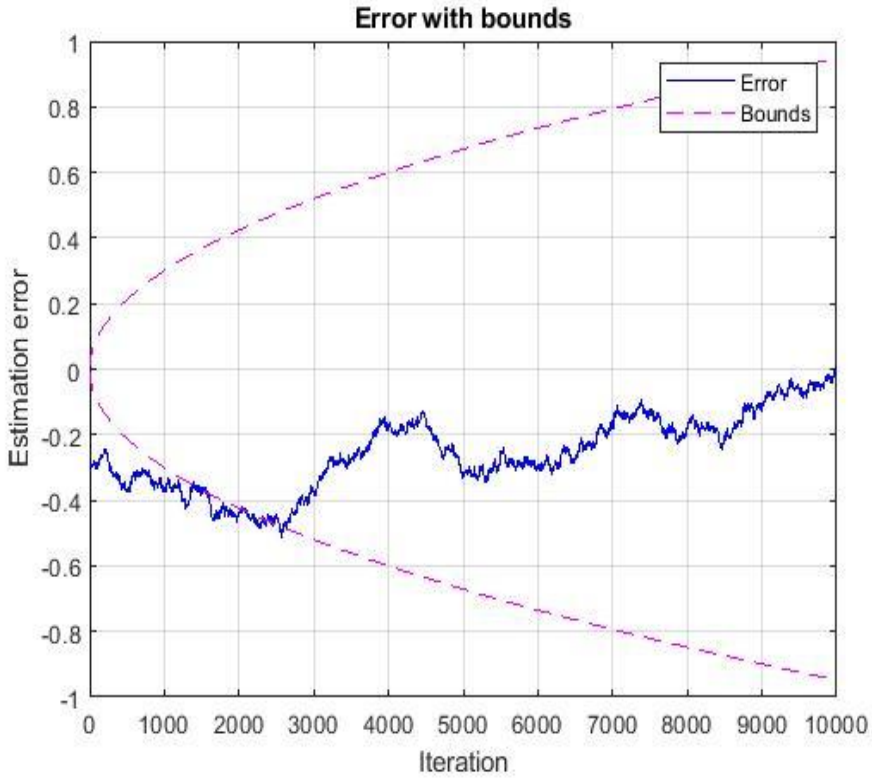


Fig.5(b) Error remains less than 0.4 in this case

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c) When the true value and initial value have a very large difference then the Kalman filter algorithm fails to estimate.

Fig.6(b) Error remains less than 0.6 in this case

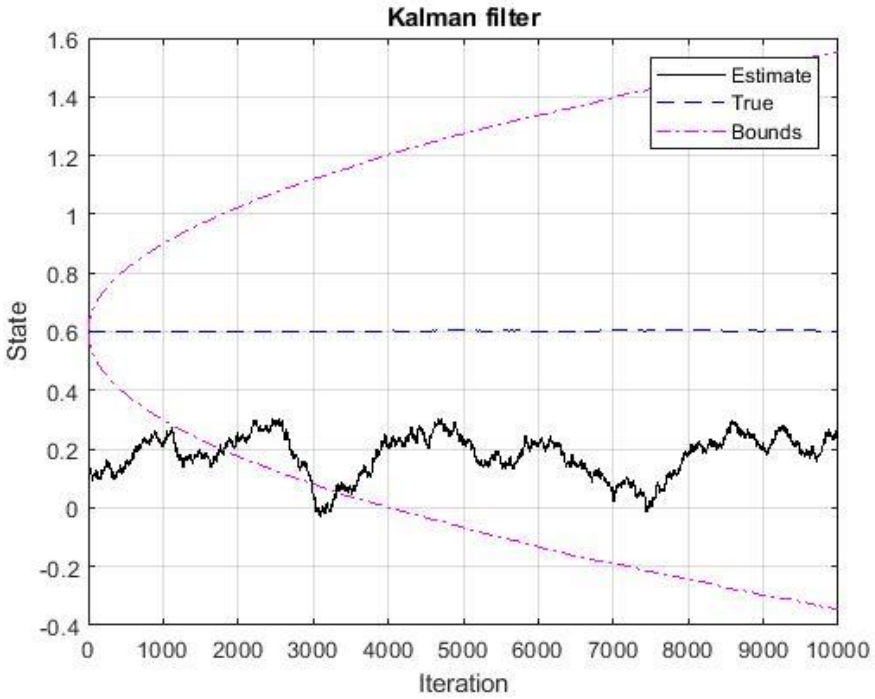


Fig.6(a) SOC estimation failed after increasing true value.

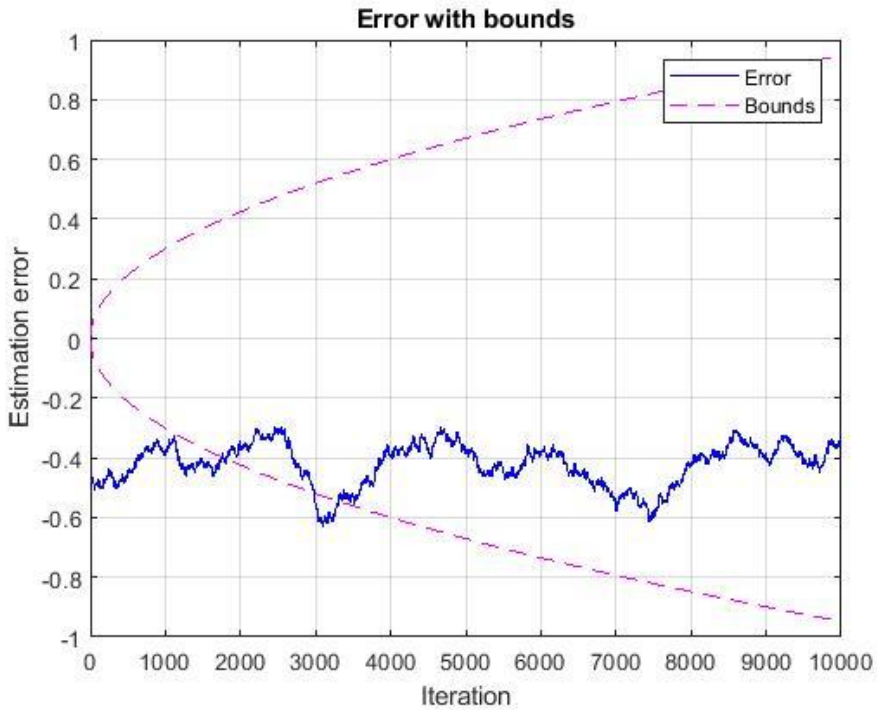


Fig.6(b) Error remains less than 0.6 in this case

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Conclusion: Among the key challenges in utilising batteries effectively is the accurate estimation of their State of Charge (SOC), a critical parameter that indicates the remaining energy capacity available for use. To address this challenge, the Kalman filter algorithm has emerged as a popular choice for SOC estimation. The Kalman filter algorithm operates by iteratively updating the SOC estimate based on a combination of measurements from the battery and predictions from a mathematical model. However, its performance can be influenced by factors such as the complexity of the battery model and the range of SOC values being estimated. While the Kalman filter excels at estimating small SOC values with high accuracy, it may encounter limitations when dealing with larger SOC values, requiring more iterations and computational resources. In practical applications, the efficiency of the Kalman filter algorithm becomes apparent during the implementation phase. If the estimated SOC deviates significantly from the true value, the algorithm may necessitate a greater number of iterations to converge to an accurate estimate. Moreover, when there are substantial differences between the initial SOC estimate and the true value, the algorithm's performance may be compromised, leading to inaccurate estimations.

Acknowledgement

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DESIGN, IMPLEMENTATION AND A COMPARATIVE ANALYSIS OF A ROBOTIC ARM SYSTEM USING BLUETOOTH TECHNOLOGY

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Abstract

This paper presents the design and implementation of a robotic arm controlled via Bluetooth technology. The system integrates a Bluetooth module, a microcontroller, servo motors to enable wireless communication between a mobile device and the robotic arm, and a DC motor for the robotic vehicle. The user can remotely command the arm's movements through a dedicated mobile application, offering flexibility and convenience in various applications. The study outlines the hardware and software components, as well as the communication protocol employed. Research findings demonstrate the effectiveness and precision of the Bluetooth-controlled robotic arm. This study contributes to the expanding field of remote-controlled robotic systems, offering a cost-effective and user-friendly solution for various industrial applications. This paper investigates a Bluetooth-controlled robotic arm mounted on a vehicle, exploring its design, control architecture, and applications for efficient movement between locations. It contributes insights into developing mobile robotic systems with improved mobility and remote-control capabilities.

Keywords

Arduino, Robotic arm, Robotic systems, Bluetooth technology, Robotic Vehicle.

Introduction

In recent years, the integration of robotics and wireless communication technologies has opened new frontiers in the field of automation. This research paper delves into the development and performance evaluation of a robot arm controlled through Bluetooth connectivity. As the demand for these remotely operable robotic systems continues to grow, the utilization of Bluetooth as a control interface provides an efficient and flexible solution. This study aims to address the challenges and opportunities associated with employing Bluetooth technology for real-time control of robotic arms [1]. By exploring the intersection of electronics and wireless communication, our research contributes to the ongoing process of enhancing the capabilities of robotic systems in diverse applications, ranging from industrial automation to assistive technology. The paper unfolds the usage of robotic control methodologies, emphasizing the need for wireless communication in

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dynamic and complex environments. Furthermore, the paper examines the potential applications of Bluetooth-controlled robotic arms. Through performance assessments, we aim to provide insights into the feasibility and efficiency of Bluetooth as a control medium in comparison to its traditional wired counterparts. This paper also contributes to the growing body of knowledge in the realm of wireless robotic manipulation. The adoption of Bluetooth technology for controlling robotic arms not only extends the operational range but also offers a platform for future advancements in human-robot interaction [2,3]. This paper provides a channel for further innovations and applications in the evolving domain of automated systems.

Literature Review

The authors of paper intend to provide a voice-controlled robotic vehicle, aiming for it to be a secure way to perform the desired task [1]. The movement of the robot is controlled by two DC servo motors connected to a microcontroller at the receiver's end. Though the paper mentions it as a flexible solution as the tasks can be accomplished by just listening to the user's commands, this setup will be ineffective in the case of industrial implementation as the industries encounter huge background noise, making it difficult for the command to be interpreted. During the COVID-19 pandemic situation, when the risk of spreading the virus was through being in contact with an affected person, engineering a secure pick-and-place robot mentioned in the paper ensured the safety of everyone around the globe [2]. Many common citizens, doctors, and paramedics became its users. Analogous to the above-cited paper, the authors of the paper have put an emphasis on the design of a robotic arm through the same wireless Bluetooth technology, proving it to be an effective and feasible solution for the era [3]. The authors also introduced kinematic and dynamic mathematical models for positioning the robot's arm and calculating the torque required to move each joint. The movements of the arm are controlled through the pulse width modulation technique. The central idea of the authors of paper is to create a robotic arm with three degrees of freedom [4]. The model described in the paper is a miniature version of an arm that mimics human operation using potentiometers at its joints. The exchange of data takes place via a Bluetooth interface. The paper describes a robotic arm with 5 degrees of freedom [5]. The arm consists of four rotatory joints and an end effector, powered by a servo motor. The authors in paper features a robotic arm with a soft gripper and four motors to control the movements [6]. The paper also includes mathematical models for torque calculations and testing methods. In addition to Arduino, the paper also uses NUC140VE3CN development boards for wireless control [7]. The robotic arm proposed in paper uses Wi-Fi technology with a Raspberry Pi board for the transmission of data, which is a bit expensive and complex from the point of view of the users, making it inefficient for the usage of a common man [8].

Problem Formulation

The Bluetooth-controlled robotic arm system developed in this research offers a solution with a

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wide range of applications in situations similar to COVID-19. It focuses on contactless operations, which include sanitization, sample collection, etc., reducing the risk of virus transmission. The proposed system supports remote healthcare assistance, logistics automation, and social distancing enforcement, which has become a necessity these days, particularly in the field of health and hygiene. By providing an adaptable robotic solution, it contributes to minimum human exposure, making it an efficient technology.

The robotic vehicle in compliance with the robotic arm not only focuses on the mobility but also on the flexibility of the Bluetooth-controlled robotic arms [5,6]. The wheels attached to the robotic arm make it more useful for the distant coverage of picking and placing the objects. The lack of wheels would have limited the robotic arm's applications.

The robotic vehicle provides certain features, which are as follows:

- Dynamic movement and stability: The controlled movement of the model makes it suitable for even using it on uneven surfaces.
- Bluetooth range: The Bluetooth module will not provide a high range of communication as provided by the Wi-Fi, but using it will decrease the complexity of the model, making it advantageous and even useful for smaller tasks.
- Remote control interface: The study uses a well-planned robot-human interaction, making it convenient for the masses.

The research aims to contribute to the advancement of robotic applications and make them known to the public at large.

Methodology

A. The Proposed Model

To make the system cost-effective and reliable, we have put forward a model that has two parts:

1. The robotic arm: For picking up the object in resemblance to a human hand
2. The robotic vehicle: To move the robotic arm to different places.

We have come up with this model with the view that it can be used in industries as well as for household purposes.

B. Construction

The robotic arm uses four servomotors for its mobility. Similar to that, the robotic vehicle consists of four DC motors. The motors are connected to the microcontroller by an L293D motor driver module. The linkage of the device, in our case, a mobile phone, for the exchange of data via Bluetooth, is done using an HC05 Bluetooth module. The microcontroller employed in this case is an Arduino UNO R3. We made use of the Li-ion battery for the power supply in our model.

Table I below describes the operating voltages for each of the components used.

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TABLE I. COMPONENTS USED AND THEIR OPERATING VOLTAGES

Components	Operating voltage
Servomotors	4.8V- 6.0V
DC motors	3V- 12V
Motor driver module	4.5V- 25V
Bluetoooth module	3.3V
Arduino UNO	5V

The flow of data takes place in the manner described in Fig. 1. The command is given by the mobile phone to carry out the task [4]. The instruction reaches the system with the help of a Bluetooth module. The entire model is supplied with power through a Li-ion battery. The codes are written in Arduino, which regulates the operation at the back end. The command then flows to the robotic arm, making it move to carry out the desired task.

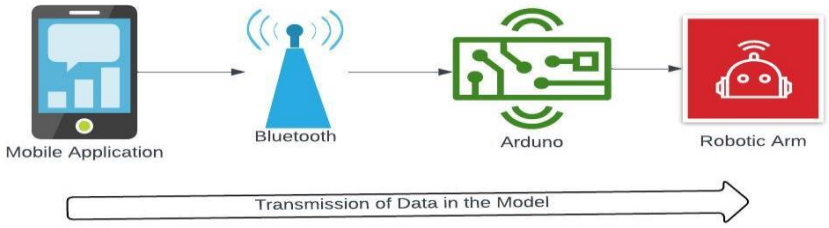


Fig. 1.Flow of data in the system

The figure 2 depicts the circuit connections for the robotic arm system. The servomotors of the arm are connected to the servomotor driver. It is linked to the Arduino board, which is then connected to the Bluetooth module and supplied by the battery source.

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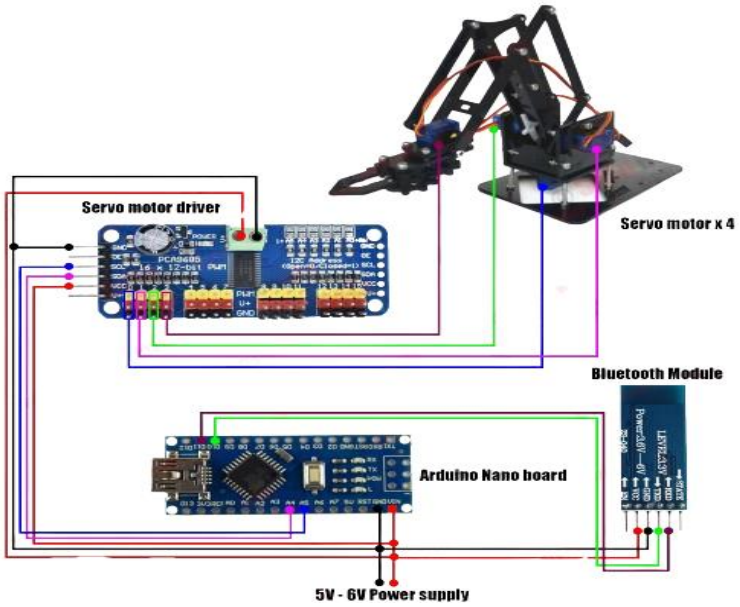
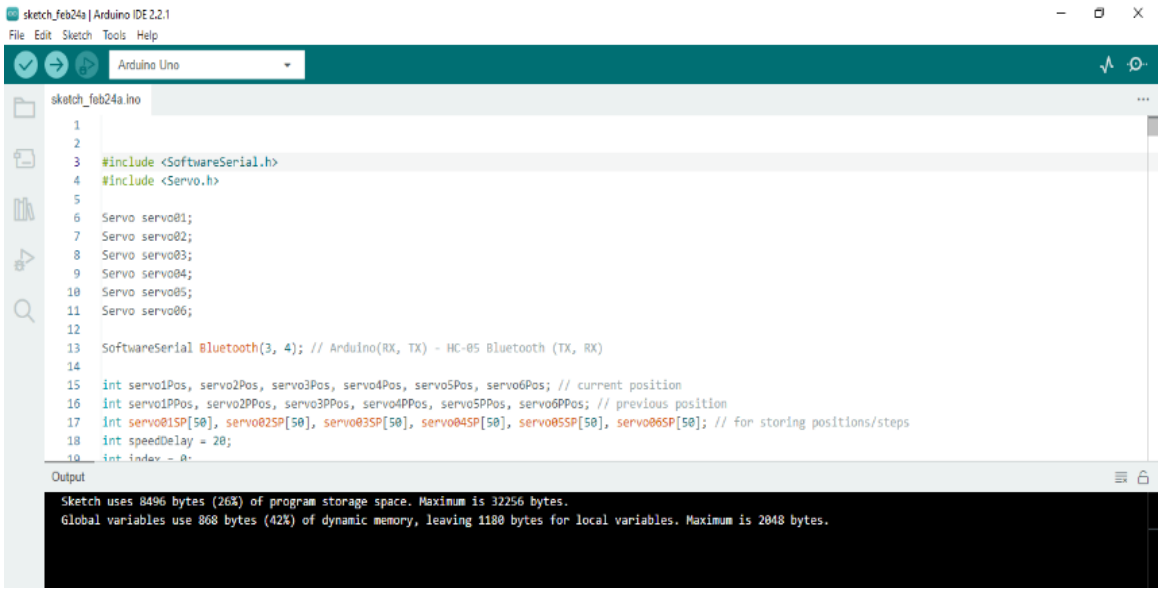


Fig. 2.Circuit diagram of the model

The robotic arm is mounted on top of the robotic vehicle. The vehicle will help the robotic arm move to dangerous zones and carry out tasks that can be harmful for humans.

C. Arduino code

The codes for the model are written in C++. The figure below (Fig. 3) shows the codes for our system.



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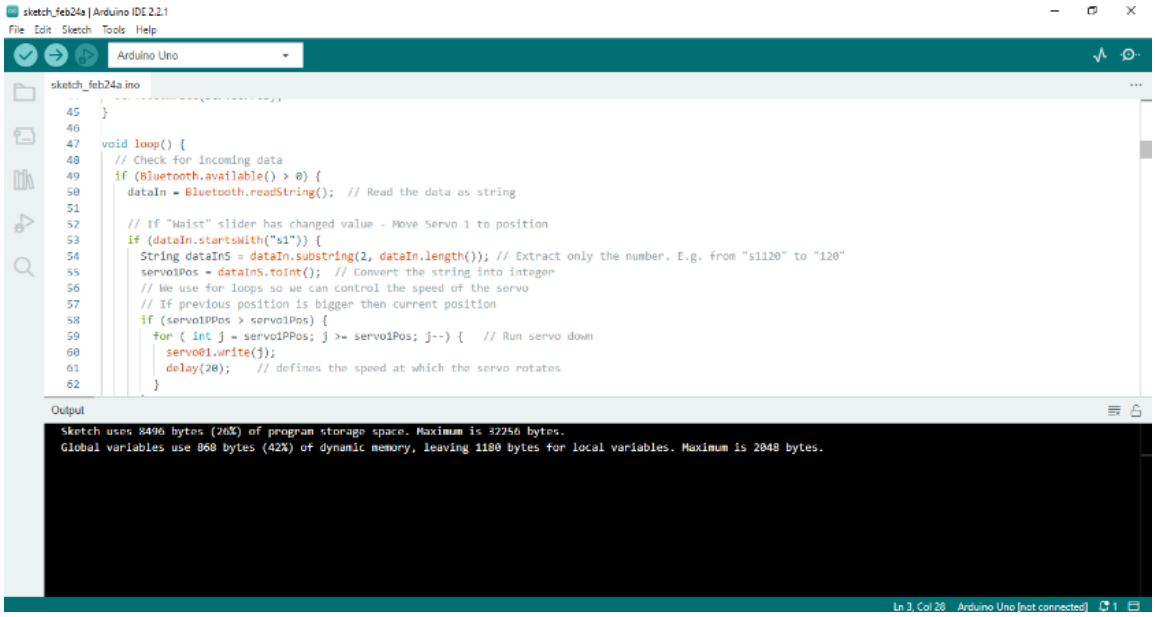


Fig. 3. Arduino codes for the model

The central idea of this model is to create a prototype, taking into consideration all the economical and feasible solutions that will be similar to a human arm movement. Through the combination of wireless technology and robotics, our prototype not only caters to the needs of various industries, but can even be used for daily household tasks. This goal is only possible if the robot-human interaction is user-friendly.

Results and Discussion

We have engineered the prototype of a mobile robotic arm, considering its broad applications in today's world. Our model consists of four joints similar to those of a human hand [3,7]. It has the shoulder joint, the elbow joint, the wrist joint, and a gripper joint. Fig. 4 below shows the robotic arm being controlled by a mobile phone.

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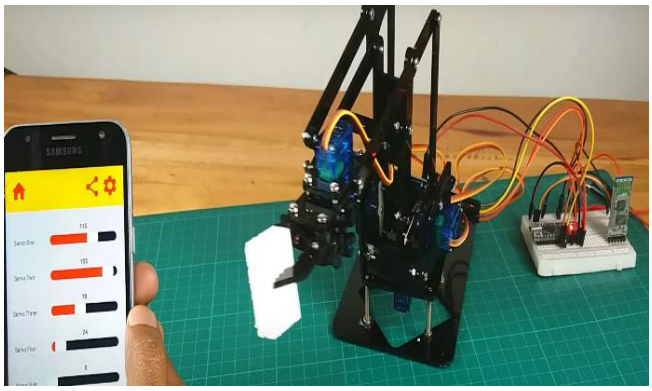


Fig. 4.Robotic arm

A human being, for example, requires his hands to pick up an object and his legs to travel to a position to place it, without which mobility becomes a difficulty; similarly, our model includes an arm to pick up the thing and wheels to move from one point to another. Fig. 5 depicts our model for robotic arm.

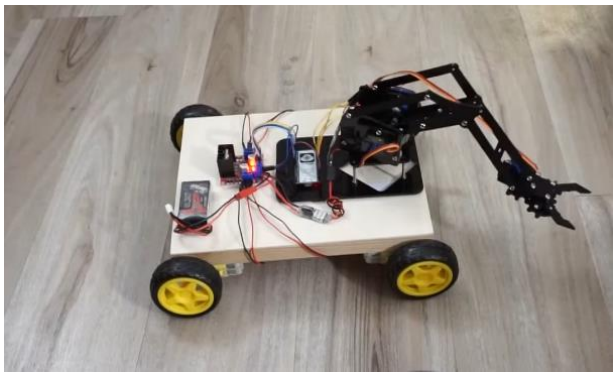


Fig. 5.Robotic arm model

The program uploaded to the Arduino serves as an facilitator, bridging communication between the mobile application and the robotic arm system. This setup enables users to control the robotic arm remotely using their mobile device. Here's a breakdown of how the system functions:

1. Mobile Application Input: Users interact with the robotic arm and wheel system through a mobile application, issuing commands via a user-friendly interface. These commands are transmitted wirelessly to the Arduino board, typically using Bluetooth or a similar communication protocol.

2. Arduino Processing: Upon receiving commands from the mobile application, the Arduino microcontroller processes the incoming data. It distinguishes between commands intended for the robotic arm and those for the wheels, ensuring the appropriate actions are taken.

3. Robotic Arm Control: For the robotic arm:

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- **UP**: The Arduino activates the appropriate motors or actuators to raise the arm, lifting it to the desired height.
- **DOWN**: Conversely, this command triggers the motors to lower the arm, bringing it down to the specified position.
- **LEFT** and **RIGHT**: These commands cause the arm to move horizontally in the corresponding direction.
- **OPEN** and **CLOSE**: The Arduino controls the gripper mechanism of the arm, widening or closing the jaw to grasp or release objects.

4. Wheel Control: For the wheels:
    - **FORWARD**: Upon receiving this command, the Arduino instructs the wheel motors to rotate in a manner that propels the system forward.
    - **BACKWARD**: Similarly, this command prompts the motors to rotate in the opposite direction, causing the system to move backward.
5. Execution of Commands: Depending on the received commands, the Arduino sends signals to the robotic arm and wheel actuators, initiating the desired movements. For example, when the "UP" command is received, the arm motors are activated to lift the arm, while the "FORWARD" command engages the wheel motors to move the system forward.

Proposing a system is easy, but deploying it in the field is a challenge. It can be put into practice only when people are aware, updated, and ready to accept the new technology [7,8]. In accordance with this, we carried out a survey to know the mindset of people related to robotics. The feedback was collected from our peers, numbered forty- three. The results are shown below in the form of graphs. Here, 1 indicates low, 2 indicates medium, and 3 indicates high. The results are shown in keeping with the above indications.

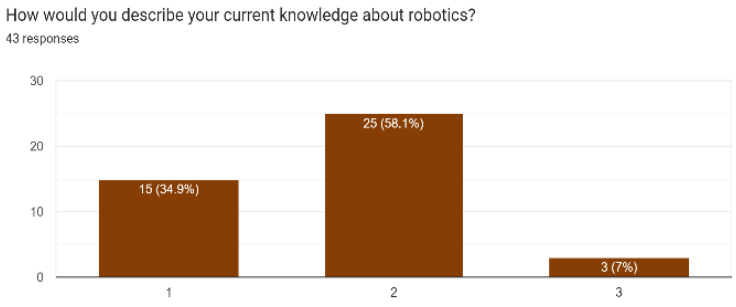


Fig. 6.The Public's knowledge about robotics

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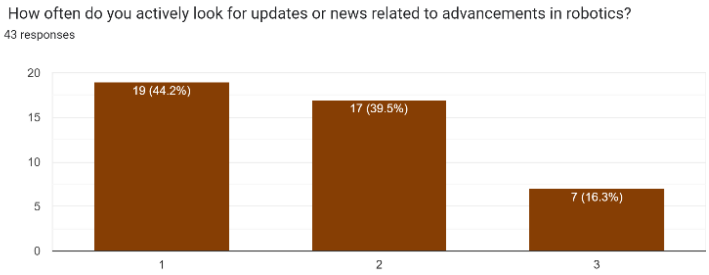


Fig. 7.The Public's keenness to know about robotics

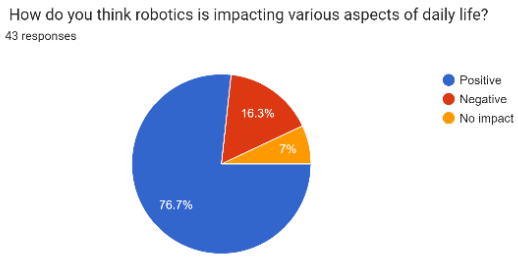


Fig. 8.Impact of robotics in our daily lives

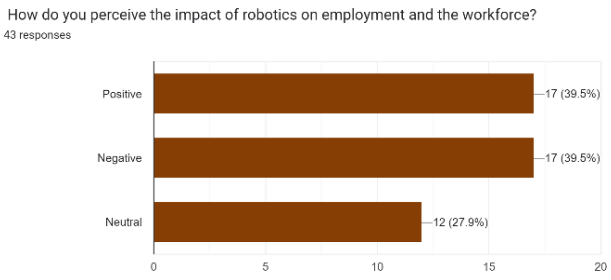


Fig. 9.Impact of robotics at workplaces

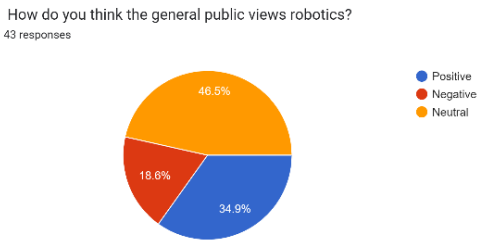


Fig. 10. The Public's general view on robotics

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These data clearly show that the community is either not updated or is out of reach of the sources in order to be able to apply robotics for their personal or professional work. This can change when robotics is included in the curriculum of students in schools and universities and awareness is created among masses. It will not only be beneficial for them but also for the nation and the world at large.

Future Scope

The future of Bluetooth-controlled robotic arms will have significant advancements across diverse domains. These arms can includee advanced obstacle detection through real-time sensor technologies and intelligent algorithms, enhancing adaptability and safety in various environments. In the medical field, precision and delicacy will be prioritized, allowing surgical procedures with improved control and feedback systems. Wi-Fi integration will extend communication capabilities, enabling collaboration among multiple robotic arms for complex tasks. Cloud-based solutions will support remote operation and monitoring, which are particularly valuable in hazardous scenarios. Efficient data storage mechanisms will log and analyze performance over time, with strict security measures in place for sensitive applications like medical data. Finally, artificial intelligence will play a pivotal role, enabling adaptive learning for optimized movements based on historical data and intuitive control through machine learning-based gesture recognition. This holistic approach underscores the potential for creating safer, more efficient, and intelligent robotic systems across a spectrum of applications.

Conclusion

The research paper has explored the integration of a robotic arm controlled by Bluetooth within the context of a robotic vehicle, also governed by Bluetooth technology. Through systematic investigation and analysis, this study has revealed the successful amalgamation of these technologies, showcasing their synergy and potential applications in diverse fields. Our study affirms the effective coordination between the Bluetooth-controlled robotic arm and the robotic vehicle, emphasizing their collaborative functionality. The implications of this research extend beyond individual components, offering a comprehensive solution for tasks that demand both mobility and manipulation, such as autonomous logistics or remote operations in hazardous environments. Despite notable characteristics, it is crucial to acknowledge certain limitations, including challenges in real-time responsiveness and potential interference in Bluetooth communication. These limitations point towards future research directions, urging the refinement of the system for enhanced performance and reliability. The exploration of a Bluetooth-controlled robotic arm on a robotic vehicle not only expands the horizons of technological innovation but also defines the potential for transformative applications in the broader domain of robotics.

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IOT BASED TREADLE PUMP AND SMART FLOW MEASUREMENT DEVICE FOR IRRIGATION

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Abstract

A treadle pump is a leg operated suction pump and it is mainly used for irrigation in rural areas. This system can be used to increase the availability of water for domestic use and irrigation of backyard gardens. This measure allows small-scale farmers to harvest rainwater in ponds and supply for gardening in the dry season. Flow measurement is a basic requirement in applications where specific and accurate amount of fluid is required. But the main problem with most of them is, they are costly and they lack the advanced technology of flow data sharing to other devices. In this work, a smart flow measurement device is developed which is integrated with the IoT to collect and monitor the flow measurement data over the internet. The output of the sensor can be collected on smart phone or any web- application of daily volume usage.

Keywords: Water management, water harvesting, irrigation, treadle pump, sensor.

1. Introduction

Finding sufficient water for irrigation and other uses is one of the major challenges facing farmers in rural India. It is too expensive for small farmers to buy, run and maintain electric powered irrigation pumps. Many a times, water is collected from a canal, pond, underground well up to a depth of 7 m manually. Development of Y type human leg operated treadle pump for various applications is of immediate interest for lifting water from ponds, canals, etc. [1]. Recently, the treadle pump (Fig.1) has many modifications to make it efficient and reliable for various irrigation applications [2].The Haryana state government has come out with a plan of rehabilitating over several thousand ponds to ascertain its suitability for irrigation and other uses [3]. IoT based applications may improve its utility for practical applications in rural areas. Pulses from microcontroller is transferred to the phone via Bluetooth, and then flow is calculated [4]. Hall effect sensor can be used to calculate flow rate for irrigation [5]. A water flow measurement system is

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used to measure the flow in irrigation and gives output in digital form [6]. A hall effect-based water flow control system was developed, which supplies required amount of water to the crops [7].

A lot of work has been done in this field to improve the flow measurement system, in terms of cost and reliability. But, most of them have not integrated in a proper standalone device, which can be used to measure flow efficiently. In this work, IoT enabled treadle pump is developed which can control and monitor the working of treadle pump remotely.

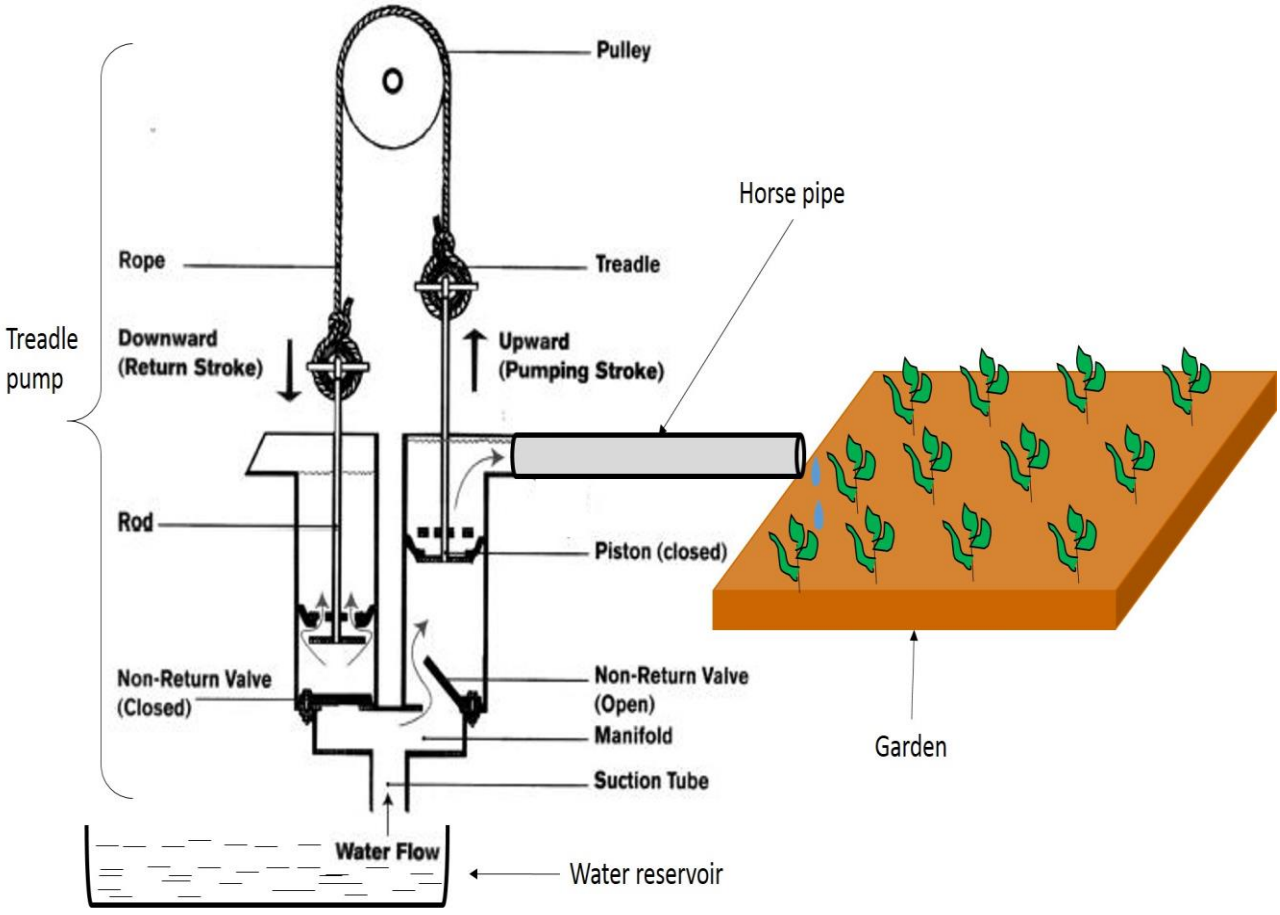


Fig. 1. Working of Treadle Pump

2. Materials and Methods:

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At present the treadle pump operation not continuous. Further, the pumps are not used in village ponds. In the present work, a treadle pump is designed which overcomes the present problem of tiresome operations and it is connected to concrete foundation system. A hall effect-based sensor is used to measure the flow of water. According to hall effect, when magnetic field is applied perpendicular to the current carrying conductor, emf is induced perpendicular to the direction of current flow and magnetic field.

Table 1- Specifications of Sensor used

Working Voltage	5~8 Volt
Max. Current Drawn	15mA@5V
Accuracy	±10%
Min Flow Measure	1 L/min
Max Flow Measure	50 L/min
Pulses per Litre	450
Inlet Diameter	11 mm
Outlet Diameter	11 mm

Table 2. Specifications of ESP8266 Node MCU Micro-Controller-

Wi-Fi Standards	IEEE 802.11 b/g/n
Digital I/O Pins	16
Analog I/P Pin	1
Flash Memory	4 MB
Input Voltage	80 MHz

Table 3. Treadle Pump Specifications

Max. Flow Rate	2500 L/h
Suction Head	4 m
Discharge Head	6 m
Weight	12 Kg

All this data is transferred to the web server using Esp8266 Wi-Fi module.

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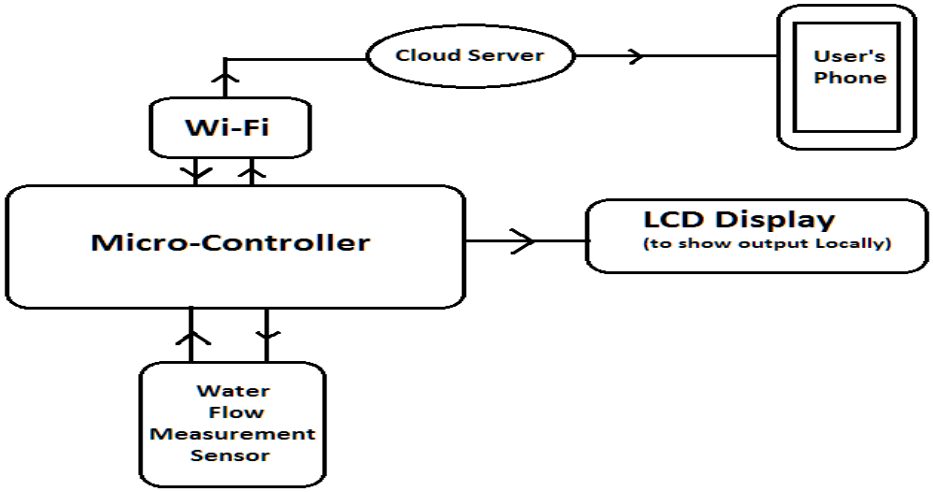


Fig. 2. Flow measurement IoT based work-flow

Treadle pump supplies water when operated up and down by foot. The water flow is sensed by sensor which generates pulses depending upon flow rate. Sensor output is supplied to microcontroller. Microcontroller gives output to control the functions with his smart phone. The flow rate reading is supplied continuously in smart phone through an App (Figure 2).

3. Results and Discussion:

A Fabrication of IoT based Water Flow Measurement Device

A concrete sloping foundation of 9 inches' height was fabricated and the pump was fixed with the help of bolts and plates. Fig.2 shows a component of the flow measurement sensor installed in the pipeline which offer very accurate flow measurement. IoT based system and its connection with adapter are shown in Fig.3.



Fig. 3. Controller with Adapter Fabrication

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Sr. No	Time(min)	Actual Flow(L)	Flow Reading Displayed in Mobile(L)	Error (%)
1	1	40	38.9	
2	2	80	79.1	1.12
3	3.1	120	118.7	1.09
4	4.2	160	161.3	0.80
5	5.5	200	198.0	1.0

B *Data accessing*

The main advantage of Internet of things is it can be used to control or monitor our device performance remotely, on the web-browser or mobile application. In our work, the water used by the pump can be seen by both on the web-browser or mobile app.

Fig. 4&5 Thing Speak server is used to save the data as well as to see that data remotely through the webpage. Thing Speak has provided a link to view our data, across the globe, using internet.

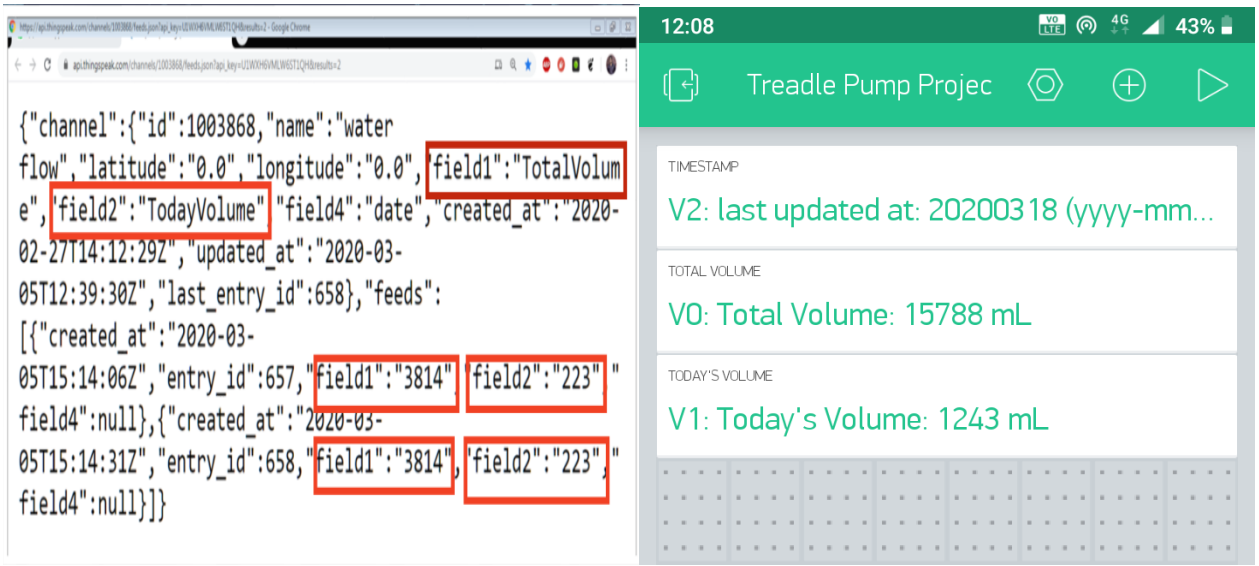


Fig. 4 & 5. Data monitoring through webpage

Table 4: Result of Flow measurement through Sensor

Smart flow measurement was achieved through IoT and error was within 1.5% and system can be controlled remotely.

4. Conclusion

Flow measurement was achieved through above setup. Smart flow measurement was achieved through mechatronics device and error was within 1.5%. Flow rate pulses generated shows the method to monitor through the mobile application using microcontroller. For making IoT based system, Blynk app is used which is freely available for Android mobile phones on the google play store.

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Also, cost effective treadle pump flow measurement is made. The cost of treadle pump without this smart flow measurement system is about 8000 Rupees, and along with this smart setup, the cost will be around 10000 Rupees. Treadle pump is operated by foot and it doesn't consume any energy. It is expected that this IoT based system may find wide applications for irrigation in rural area.

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A COMPREHENSIVE REVIEW OF BIO 3D PRINTING MATERIALS

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ABSTRACT

The field of 3D bioprinting has been explored a lot in the field of different materials and exploring so many new materials to make the process easier. This study focuses on the latest developments, challenges and the future scope of Additive Manufacturing in the Medical Field. 3D Bio-printing has the vast scope in the field of Tissue Engineering and Regenerative Medicine.

The Significance is on the broad multifariousness of biomaterials, scaffolds, and bioinks that are used in this ingenious field. Additive Manufacturing is a very prominent and effective Technology in the field of Tissue Engineering, Regenerative Medicine and Patient rehabilitation for the patients suffering from neurodegenerative disorders like amyotrophic lateral sclerosis, traumatic brain injuries, or spinal cord injuries, Additive manufacturing has come out a very prominent technology. It is proving to be a low-cost and desired technology, can make complex structures, and customized organs can be made easily according to the patient. Although, additive manufacturing in Bio-Medical fields is facing a lot of challenges along with the ease of its usage. The inadequacy of hydrogels, polymers, biomaterials, and bioinks that possess the major qualities. This is inclusive of biocompatibility, suitability, for 3D printing, and remarkable biomechanical performance able to mould and accept different and vast variations of requirements. The rarefaction of such materials into capable devices with customizable biomechanics, Excellent architectures, controlled blemish rate, and required bioactivity remains a continuous challenge within the field. Therefore, it becomes essential to affirm the current developments in the realm of biomedical Additive Manufacturing. Along with that we have to conduct a broad analysis of the price, ease of manufacturing, printing ability, mechanical properties, biocompatibility, and degradation rate of different materials, hydrogels and bioinks. This broad analysis will give the valuable and prominent analysis into the potential of 3D bio fabrication.

KEYWORDS

Additive manufacturing, Tissue engineering, Regenerative medicine, Bio fabrication, 3D printed scaffolds.

INTRODUCTION

Visualize a world where Transplant of Organs are no longer sporadic, where complex tissues can be manufactured outside the body and can implant or transplant, and where customized medicines are easily available according to the need of the body of different patients. It is very brilliant to fantasize the future with all these facilities, personalized healthcare, and the manufacturing of Human organs? Field of additive manufacturing in biomedical is self-explanatory. This versatile technology allows the scientists to manufacture 3D structure with the process of layering the living cells to construct the relevant structures. In this study an Insight of 3D bioprinting materials will be discussed. The process that made this field so accurate and available in Tissue engineering, customized medicines, and materials. This is the goal of 3D bio fabrication, a revolutionary field that combines the precision of 3D bioprinting with the complexity of biology. Additive Manufacturing in bio medical field plays and important role and provides a promising avenue for Tissue engineering, drug recovery, and personalized healthcare. To completely make this field feasible, affordable and reliable from every respect, from medicine to organs. From synthetic polymers to bio-compatible hydrogels, this study will deal with the utilization and challenges of different materials that have been used in additive manufacturing in biomedical sciences.[7]

Bio 3D Printing Materials:

Bio 3D printing materials are a crucial aspect for the manufacturing in bio medical sciences. These materials perform several tasks and the complete structure and its properties is completely reliable on these materials only, growth and generation of scaffolds [9] of the printed object depends on the material. Following are the different types of materials used in 3D bio printing.

Synthetic Polymers: Building the Foundation of Bio 3D Printing

Synthetic Polymers [5] serve as the chief support in the field of bio 3D printing, it provides mechanical solidity and structural support. These materials can be mould to meet different requirements such as biodegradability, biocompatibility [10][15], and cytocompatibility. Following is the some commonly used synthetic polymers in bio 3D printing:

Poly (lactic acid) (PLA)

- PLA is a biodegradable and biocompatible polymer extracted from renewable resources such as cornstarch or sugarcane.[15]
- It is extensively employed in tissue engineering, drug delivery, and scaffold [13] fabrication due to its desirable printing ability and mechanical properties.
- PLA is feasible and compatible with different cell types and able to degrade naturally over time make it a prominent choice in bio 3D printing.

Poly (ethylene glycol) (PEG)

- PEG is a hydrophilic polymer has excellent biocompatibility and low toxicity and very feasible in every scenario and with different living cells.

- Its nature of crosslinking with other materials and polymers makes it easier to combine with other material in order to form a hybrid material with enhance qualities, durability and enhance mechanical properties.
- PEG materials closely resemble with natural extracellular matrix which facilitates the cell adhesion and growth which makes it usable extensively in tissue engineering.

Poly(caprolactone) (PCL)

- PCL is a flexible material [19] and has excellent printability and mechanical strength which makes the polyester's utilization on a large scale.
- PCL degrades with the very slow rate which make the scaffolds provide extensive support for tissue regeneration.
- PCL-can be used in cartilage and bone tissue engineering.

Biocompatible Hydrogels: Encouraging Cell Growth and Differentiation

Hydrogels play a versatile role in additive manufacturing by providing a suitable environment and make the most prominent replica of the extracellular matrix.[11] These materials are feasible to inject and print and because of these two qualities it is really helpful in the production of tissues and organs. Following are some examples of biocompatible hydrogels:

Gelatin

- Extracted from collagen, gelatin that offers excellent biocompatibility and biodegradability.[6]
- It is feasible and promotes cell adhesion, proliferation, and differentiation which makes it preferable in tissue engineering.
- Gelatin-based hydrogels are very soft and that is why they are suitable for soft applications like skin and cartilage regeneration.

Alginate

- Alginate is polysaccharide derived from brown algae that occurs naturally, it is known for its biocompatibility and gentle gelation process.
- It offers cell-favoring survival because the oxygen gets diffused within the cell. It contains a high amount of water and porosity facilitates nutrient.
- Alginate hydrogels are more useful in wound healing, drug delivery, and the bio fabrication of pancreatic islets.

Hyaluronic Acid (HA)

- HA found in the extracellular matrix, is a glycosaminoglycan, providing hydration, lubrication, and cell signaling.
- It is an excellent choice for the formulation of bioink due to its ability to store water and biocompatibility.
- HA-based hydrogels are more useful in tissue engineering [17], especially for involving cartilage and skin regeneration.

Hybrid Materials

Hybrid materials are the combination of synthetic materials and natural materials in order to make the material more prominent with enhanced qualities. Hybrid materials are made by combining two or more good materials with enhanced qualities. Following are some Examples of hybrid materials used in bio 3D printing.

Hydrogels:

It is the combination of hydrophilic polymers; hydrogels possess high water content. It resembles the native extracellular matrix. in order to achieve the mechanical strength and biodegradation rate, they are often crosslinked with synthetic polymers.

Bio ceramics:

The most Suitable and best example for Bio ceramics is calcium phosphate, it has excellent biocompatibility with mechanical robustness. Extensively used for bone tissue engineering and dental applications.

The Importance of Materials in 3D Bioprinting:

Additive Manufacturing is the revolutionary field that combines the principles of 3d printing with regenerative medicine, Tissue Engineering. 3D Printing involves the creation of 3-dimensional structures using biomaterials and Living cells, with the Aim of manufacturing functional Tissues and Organs.[16] The concept of bio-Printing is inspired in itself, and the selection of Materials is the most important Factor. The Success of the Constructed Structure is heavily relied on the selection of material on the basis of Compatibility, and properties of theMaterials.

1. Biocompatibility and Cell Viability

In 3D Bioprinting, Materials has to be biocompatible, which means they do not release harmful immune responses or toxicity when the structured organ or tissue comes in contact with the living cells. Along with the bio compatibility material should support cell viability and promote cellular Functions such as generation and discrimination. Hydrogels plays a vitalrole in the formation of 3D Structure. In 3D bio printing natural polymers are of major use because they extracted from natural sources and their bio compatibility and ability to mimic extracellular matrix. Commonly used natural polymers are alginate, collagen, and gelatin.

2. Structural Integrity and Printability

For Successfully building complicated Tissue and Organ Structures, Materials must have adequate Mechanical Strength and structural integrity. Material should be of a type that it should retain their shape during and after the printing process to ensure precise and reliable fabrication. This is the required quality for the materials with relevant viscoelastic properties. It must possess the ability to undergo shear thinning behavior, which means that material can flow during the printing process and after printing it will solidify and maintain structural integrity. Example; Polyethylene Glycol (PEG), Hydrogels and light-curable Bioinks [12].

3. Biochemical and Physical Cues

Tissues present in the Human Body are of complex architecture and functionalities and it completely depends on a combination of physical and biochemical clue. Materials used in 3D bioprinting should be of type that they will be able to provide the clue to guide cell behavior and development of the tissue. Incorporating factors for example proteins, peptides, and growth factors also the electrical and mechanical stimulation the materials can promote cell adhesion, differentiation, and tissue maturation.

4. Degradation and Tissue Integration

While processing the 3D bio printing few things should keep in mind and the most important part is that the material will degrade over time and allow the integration of newly formed tissues. This nature is to be only able to get with the help of natural polymers. Degradable materials promote the regeneration of functional tissues, they gradually breakdown and gets replaced by native extracellular matrix components. From this perspective, Polylactic acid (PLA), poly (lacticco-glycolic acid) (PLGA).

Applications of 3D Bioprinting Materials:

3D Bioprinting materials are essential for two fields Tissue Engineering and Regenerative Medicine. These by materials help to enable the development of functional biological constructs by enabling the creation of 3-Dimensional Structures that would completely resembles characteristics of living tissues.

Following are the important 3D bioprinting Materials:

Tissue and Organ Engineering:

Organ Transplants:

3D bioprinting materials are used to make organs by using scaffolds and bio inks and with the use of different manufacturing Techniques. This cutting-edge technology is able to develop working organs that reduce dependency on donor.

Bone and Cartilage Regeneration:

By using different Techniques injuries, defects and wounds can be treated by using bioprinted scaffolds, it promotes the growth of new bones and cartilage tissues.

Drug Development and Testing:

Pharmaceutical Testing:

3D bio printed materials offered a more precise and accurate human physiology environment in comparison to 2-Dimensional cell cultures. 3D bioprinting is very helpful in drug testing.

Disease Modelling:

3D bioprinting plays a vital role in examining and interrogating the cause of particular disease by creating the tissues and a particular physiological environment.

Biomedical Research:

Cell and Tissue Studies:

Researchers used 3D bio printing technology to build blueprint models, it is to study cell behavior, interactions, and responses.

Cancer Research:

Researchers create the bio printed tumor Models to understand the course of cancer, test new treatments and drugs. It gives the better understanding.

Personalized Health Care:

Patient-Specific Implants:

3D bioprinting [20] reduces the risk of rejection and life loss by introducing the personalized organ and Tissue development, by examining the Human Anatomy for the particular patient. It also lowers the risk of implant rejection.

Skin Grafts and Wound Healing:

Skin Substitutes:

3D bio printing makes the treatment of wounds and burning much easier because it is capable to create even skin substitutes. It is possible in conventional skin grafts.

Dental Applications:

Tooth and Jaw Reconstruction:

3D bio printing is playing a vital role in the field of Dental also, it is used to regenerate dental tissues and jawbone and teeth. It is also helpful in the treatment of craniofacial abnormalities and tooth loss.

Engineering Neural Tissue:

Nerve Regeneration:

3D bioprinting is also helpful in the treatment of neurological illness and spinal cord injuries. It promotes the growth of new neural tissues.

Engineering of Vascular Tissue:

Blood Vessel Constructs:

By using 3D bioprinting, vascular structures that can be incorporated into engineered tissues and support healthy blood flow and nutrient exchange can be produced.

Food Sector:

Production of Cultured Meat:

3D bioprinting materials are very useful for even for the meat production. 3D bio printing s playing a vital role in meat production also. It is an alternative method to traditional meat production.

Educational and Training Purposes:

Medical Training Models:

3D bio printing is also helpful in teaching in medical institutions for teaching purpose for practicing real time surgery in a real-world environment by creating replicas of tissues and organs.

Unleashing the Potential of 3D Bio fabrication

1. Revolutionizing Organ Transplantation

Overcoming the Organ Shortage

Shortage of donated organs is the major issue in worldwide. According to World Health Organization, only 10% of the requirement met. This is the very critical scenario and led to immense suffering and loss of lives. However, 3D bioprinting plays an important role in this critical scenario. Scientists are making immense growth in creating functional organs, for example hearts, kidneys, and livers, using a patient's own cells. With the help of layering these cells in controlled manner. It is possible to construct a functional organ and tissues which resembles their counterparts.

Eliminating the Risk of Rejection

Organ Transplant field is facing the major issue is of organ Rejection. Because the organs soured from donors, the major concern is immune system compatibility. 3D bio printing field is making this scenario very easier by personalizing the organ construction, by using the patient's own cell for the construction. The risk of rejection is almost eliminated. 3D bio printing fabricates replica of the organs that is the exact match of the immune system of the patient.

Advancing Regenerative Medicine

Healing Wounds with Bioengineered Skin

3D bio printing is also helpful in dealing with chronic wounds, for example diabetic ulcers, its treatment was the challenge for the medical field. However, 3D bio printing resolves the issue and make the treatment of diabetic ulcer possible. It offers revolutionary solutions for the wound healing.

Using biocompatible materials and living cells researchers was able to fabricate the replica of organs and tissues also to regenerate skin substitutes which is helpful for the treatment of skin wound and burning. It also makes the healing faster because of the new skin and prevents complications. It also promotes the growth of new tissue which improves overall outcomes.

Repairing Cartilage and Bone Defects

Bone and Cartilage Injuries can be exhausted and will remain for longer period and pain remains for long. Traditional treatment includes the bone replacement, but every treatment has their own limitations. But 3D bio printing revolutionized the field of orthopedics.

Researchers are actively exploring the field of bio 3D printing implant with living cells to repair and regenerate the damage cartilage and bone tissues. With the help of 3D bio printing Technology not only the construction of same structure but the integration with the surrounding tissues is possible. Which promotes seamless healing and restoring functionality.

3. Personalized Medicine and Drug Testing

Tailoring Medical Solutions to Individuals

3D bio printing introduces the concept of personalized medicine based on the genetic makeup of the particular patient and revolutionize the field Medical Sciences. 3D bio printing bought this vision to life and makes so many crucial things easier.

3D bio printing use patient's cells to create tissue models. Scientists use these models to replace tissues and organs and also for the drug testing and to identify the cause of the disease. By the Implementation of the 3D bio printing in the field of Medical Sciences. It helps the health care providers to select the optimum treatment for the disease.

Accelerating Drug Development

Processes that have been used previously are lengthy and costly, also took a lot of time for developing the drug and introducing it in the market. However, 3D bio fabrication consolidates the process.

Accurate and efficient Preclinic studies are possible with the help of 3D bioprinting models because it closely mimics the structure and physiological environment of the living cells. It also helps in identifying the drug responses and the side effects for the same, without harmingany animal by testing the drug on them. It also reduces the overall time taken in developing, Testing and Introducing the Drug.

Advancements in Bioprinting Materials

The Field of 3D bio printing is revolutionizing the medical sciences field and researchers are keep on evolving the field even more for better performance and making the treatment easier soon.

Following are the advancements in the field of bio 3D printing.

1. Decellularized Extracellular Matrix (DECM) Bioinks

Decellularized Extracellular Matrix bioinks removes the cellular components from the natural tissues, and ECM'S structural and singling molecules left behind.[3] Decellularized Extracellular Matrix bioinks provides cell adhesion, and precisely deliver therapeutic agents precisely. Researcher gets the immense success by fabricating complex tissues, including cardiac patches and vascular constructs.

2. Nanotechnology-Enabled Bioinks

Integration of the Nanotechnology in the bioinks emerged the functionality of bio printed tissues. For providing the mechanical reinforcement, improve cell adhesion can be achieved by the integration of nanoparticles and nanofibers into bio inks. Tissue Engineering led to advancements by the integration of nano materials, such as the development of bone scaffolds with enhanced strength and vascularization.[9]

3. Bioprinting with Stem Cells

Stem cells possess the ability in differentiating the various cell types which is beneficial for tissue engineering applications. Researchers are exploring the field for the integration of stem cells into the bio inks in order to enhance the regenerative potential of tissues that has been created by 3D bio printing. For getting the more functional and viable tissues scientists are integrating and trying to precisely be positioned stem cells within the printed structure.

The Complexities of Bio 3D Printing Technology

Precision and Scalability

Bio 3D printing involves the process of layering in which bioinks gets deposited very precisely and forms accurate complex structure. High precision is the foremost demand in thefield of bi medical sciences in order to make the replica of tissues and organs. Precision is thecritical aspect of bio 3D printing that has to be taken into account in order to achieve the success safety. Maintaining that precision is the critical task when it comes to complex or bigstructures.

Biocompatibility and Cell Viability

The major task in the process of bio 3D printing is to ensure the biocompatibility to reduce the risk of harm and life loss and rejection of transplant. Bioinks should be of such type that they ensure the generation and growth of the tissues and cells by degradation. However, thereis one more challenge it is to maintain the viability within the bioink during and after the printing process. Cells are reactive towards the environmental conditions such as Temperature, pH, and mechanical stresses, which can be a part of concern during the printingprocess. Bio 3D printing still needs to be explored in order to maintain the viability of the bioinks.

Vascularization and Perfusion

As Bio 3D Printing is dealing with many challenges from which one of the major concerns is the incorporation of vascular tissues within the printed tissues and organs. The Essential thing for the blood vessel network is the required nutrient, oxygen supply as well as waste removal. However, Simulating Complex Architecture and maintaining the functionality of natural blood vessel is a very critical task. By Overcoming this challenge maintaining the viability oflarge and complex tissues and organs will become possible.

Integration of Multiple Cell Types

3D bio printing has done a tremendous job when it comes to construct the organ or tissue with single cell but when it come to the integration of different and various types of living cell it is a challenge for the researchers and to overcome this challenge this field needs to be evolved even more. Various Tissues and Organs needs to be generated by the incorporation of

different cells and are complex in architecture, it is a challenge for the scientists to construct such complex structures.

The Materials Challenges in Bio 3D Printing

Selection and Development of Bioinks

Bioink is the essential part and plays a vital role in the process of bio 3D printing and it has to be of such type that it supports the generation and growth of the cells. Selection of the bioinks for making the particular organ and tissue is the challenging task. Selection of the Bioink should be accurate and according to the genetic makeup of the patient to promote the cellular growth and generation. Bioinks should be same in biocompatibility, bio functionality and printability and mechanical properties in comparable to targeted tissues and organs.

Sterility and Contamination

It is a challenging task to maintain the sterility in the printing process of tissues and organs because it is a vital process. Integration of living cells in the bio inks is more prone to contamination so it is a challenging task. Functionality of printed structures would affect with the presence of one contaminant. Aseptic Handling of the material is required, and sterilization techniques needs to be implemented to ensure the success and safety of the printed tissue or Organ.

Mechanical Strength and Long-Term Stability

It is the essential thing to ensure that the printed structure possess the same mechanical strength and long-term stability for successfully integrating the printed part in the human body. The materials that are going to be used in the manufacturing of the organ or tissue mustprovide necessary support and mechanical strength to the printed structure and fully mimic the native tissue. While printing the complex and larger architecture attaining the same strength and viability is still a challenge. Improvement in few mechanical properties is still required for the adequate performance of the printed structure as the native tissue.

Challenges and Future Directions

3D bio printing has achieved a massive growth but still encompasses some challenges that needs to overcome for wide spreading it in the Field of Medical Sciences. Below mentioned are some major challenges that needs to overcome.[4]

- Vascularization: Integration of the Vascular network in the printed structure is the major challenge in order to ensure the oxygen supply and proper nutrient supply to cells.
- Cellular Complexity: Integration of various cell types into bioink for constructing a network of tissues or for constructing complex structures is a challenge.
- Material Selection: Achieving biologically relevant tissue constructs is challenging because it is crucial to identify the material with superior mechanical properties, bio functionality, and printability.

Future Scope

- Multi-material Printing: Scientists are deeply evolving the field of 3D bio printing to get the technique which ensure the integration of various living cells in single bio ink in order to make the complex architectures possible.
- Bioinks for Vascularization: Vascularization, it is difficult tom construct the blood vessels in the organ so Researchers are working in the technique for developing that also ensuring that proper oxygen and nutrient supply will be possible.

CONCLUSION:

Bio 3D printing materials playing a vital role in the new Era of Innovation the field of medical sciences in order to construct the organ and tissues.[14] By the use of supporting materials, biomaterials, Hydrogels, Bio inks and Living cells. Scientists are kept of exploring the field for removing the boundaries that is making the field constraint to some extent. However, challenges will remain in different form but along with that advancements are also on the track such as vascularization is providing the avenues in thenear future. As the field of Bio 3D printing is keep on evolving it is making sure to get thepersonalized organs tissues and regenerative medicines to cure the wounds. This technology is giving the new frontier in the field of medical sciences. Synthetic Polymers are providing the base for hydrogels to construct a durable structure. As we are moving ahead towards vascularization and cellular complexity it is giving the new excitement in the field to evolve it even more for making the challenges of medical science to eliminate completely. By imagining the current situation and the future scopes we can imagine the near future in the field of medical science in the form of personalized organ construction and the generation the personalized medicines. This field has already evolved a lota and presenting the revolutionary performance in the field of medical sciences and keep on evolving.

So, keep an eye on the exciting advancements in bio 3D printing materials as they pave the way towards a new era in healthcare and biotechnology.

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REVIEW ON 3D BIOPRINTING TECHNIQUES AND MATERIALS

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Abstract

Additive Manufacturing has attained massive growth in the past few years and has become rapidly advanced in the field of bio 3D printing, this is an extensively revolutionary technology that can produce customized medicines and organs and is also extremely helpful and feasible in the field of tissue engineering, regenerative medicines, and other areas of scientific research.

In this study, we will get a deep review and knowledge about the materials and techniques that have been implemented in the field of 3D bio-printing for manufacturing tissues and human organs and will also understand and explore the advancements in 3D bioprinting, focusing on techniques and materials. It will highlight in the evolution of printing technologies and their strengths and limitations. This survey circumscribes the range of Biomaterials, discussing their feasibility and usage with unconventional materials and in making different organs, tissues, and medicines. This study will also highlight insights into the current situation of 3D Bioprinting and focus on the futuristic scope of the versatile technology.

3D Bioprinting is very helpful in regenerating the damaged cartilage. It is spreading its branches in all the fields of biomedical sciences and showing commendable growth in every field. 3D bioprinting is well known for the manufacturing of complex structures with accuracy and precision. Cartilage is the simplest application of 3D bio-printing. This technology can achieve an even more complex structure that is human-defined.

Keywords

3D Bio Printing, Bio Fabrication, Biomaterials, Tissue engineering, CAD.

Introduction

Bio 3D printing is well known for its complexity in the field of Biomedical sciences. Scientists are using this technology for other research and for making 3D bioprinting more feasible, accurate, valuable, and cost-effective. It is the combination of principles of additive manufacturing with the complexity of biomedical sciences. In 3D printing living cells,

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biocompatible materials, and bio-inks form a 3-Dimensional structure by layering process. The goal of 3D bioprinting is to build tissues and organs that can be used for transplantation or in vitro testing [1]. This process gives the precise replica of tissues and organs that can be used in the place of the original organ and Tissue without any delay or hassle. This technology has the potential to revolutionize medicine, from regenerative therapies to personalized organ transplantation.

Three-dimensional bioprinting not only offers the service on an immediate basis but also customized medicines and organs which can be made at very low cost and offers patients a personalized medical solution. This revolutionary technique has the potential for fabricating bioscaffolds with complex structures and geometries and specifically for use in regenerative medicines. In the last few years, the field of biotechnology has achieved massive growth which is known as 3D bioprinting which revolutionized the field of bio-medical sciences, medicines, and tissue engineering. 3D bioprinting is purely inspired by 3D printing and gives 3D printing appreciable growth by developing Tissues with the help of living cells.

The 3D bioprinting process involves the deposition of living cells, bio-inks biomaterials, and supporting material by the layering process to construct a 3-Dimensional structure. This technology mimics the precise structure of the native tissues. It is a very helpful solution to the problem of shortage of organ donors and not matching Organs. With the help of this technology personalized and customized organs and tissue can be constructed precisely. 3D bioprinting is working in the field of making the model which will serve the bioprinter as the blueprint and guide the bioink for the proper deposition. This is the major advancement till now in the field of 3D Printing. 3D bioprinting gives new heights to 3D printing.

Advancements in Bio 3D Printing

The 3D bioprinting process involves the deposition of living cells, bio-inks biomaterials, and supporting material by the layering process to construct a 3-Dimensional Structure. This technology mimics the precise structure of the native Tissues. This revolutionary technique has the potential for fabricating bioscaffolds with complex structures and geometries and specifically for use in regenerative medicines [2]. This technology holds a grip on the shortage of organ donors and reduces the dependency of the patients for organs. This technology precisely mimics the native tissues with the help of bio-ink biomaterials supporting materials and prepares a precise scaffold. This technology plays a versatile role in advancing personalized medical treatments. With the help of medical imaging data, it constructs a 3D structure in a step-by-step process. This model serves as a blueprint for bioprinter and guides the bio-ink biomaterials and supporting materials for the construction of Personalized organs and Tissue.

Review on Bio 3D Printing:

The initiation of 3D printing technology in the 15th century developed the printing industry by facilitating fast imitation of writing and pictures, foremost to extensive propagation of data with a substantial social group, governmental, and economic impact [3]. Rapid onwards to the extant, 3D printing technology is once again poised to make revolutionary supplies, intensely in the field of medicine and other industries. Since its origin, 3D printing has

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expanded significantly from its original form known as "stereolithography" founded by Charles W. Hull in the early 1980s. Nowadays, new techniques and methods have been operated and consumed for educational, examination, and even medical purposes. From STL to bioprinting, various techniques have been involved and allow the automated creation of individual tissue replicas and even organs.

The revolution of 3D printing and ecology has released modern guidance in tissue redevelopment and organ creation throughout the last period. Although extensive work, aiming for suitable bioinks and tissue forms is still demanding. Recovering the structure decision, maintaining the cell probability, and reducing the fabricated time are the main problems for new bio-ink creation and the advancement of 3D bioprinting techniques. Additionally, an attempt has been made to provide the most relevant application of 3D bioprinting techniques such as tissue regeneration, cancer investigations, etc. by presenting the most important works. They also focused on highlighting the strengths and limitations of existing biomaterials and 3D bioprinting techniques to make a comparison through them [4].

The Intersection of 3D Printing and Biology

The conjunction of 3D printing and biology has launched new ways for tissue redevelopment and organ creation over the past period. However, creating appropriate tissue structures and bioinks was a task. Key areas for improvement include enhancing structure resolution, preserving cell viability, and reducing fabrication time. The researchers have researched the various applications of 3D bioprinting techniques, such as tissue restoration and cancer studies. During these studies, the pros and cons of current biomaterials and 3D bioprinting techniques have been observed, and the similarities and potential for further expansions in the field.

Classification on Bio 3d Printing Technology:

1. Extrusion Based Bioprinting:

In the field of Tissue engineering and regenerative medicine Extrusion based technique is a well-known technique [5]. In this methodology, the flow of the bioink which is the combination of living cells and biocompatible materials is controlled and it follows the layer-by-layer process to construct the three-dimensional structure. The Extrusion technique is an advancement in the field of traditional 3D bio-printing techniques. In this technique, the material is pushed through the nozzle to form the desired shape of the targeted tissue and Organ. From the perspective of 3D bioprinting, this method is crucial for constructing complex and functional tissues and organs.

This technique involves the extrusion of the bio gel or the bio ink through the nozzle and as the printed structure gradually solidifies it allows the cells to adhere and grow.

Extrusion-based 3d Bioprinting technology revolutionized the field of 3D bioprinting and it is a versatile technology in the field of regenerative medicines. Researchers are evolving the field of 3d bio printing even more and it will play a crucial role in the advancements of the field in the development of functional and transplantable tissues.

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2. Inkjet Based Bioprinting: -

The inkjet-based bio-printing technique is an advancement in the field of traditional inkjet printing technique, and it is adapted for the deposition of bio-inks and hydrogels to construct the 3-dimensional Structure.

Ink jet-based 3D bioprinting is inspired by traditional 3d inkjet printing and uses bio-inks, biomaterials, and supporting materials with appreciable precision this is the versatility of the inkjet-based 3D bioprinting that it is very precise in comparison to other bio 3D printing techniques. The precision of this technique helps in constructing complex 3D structures [6]. Along with the versatility of this field, it is also a powerful technique in the field of 3D bio-printing. Challenges are still there but researchers are still evolving the field and pushing the boundaries to achieve the desired goals.

3. Laser-assisted bioprinting (LAB): -

Laser-assisted bioprinting (LAB) is the advancement of the 3D printing technique that uses laser technology to deposit the bio-inks. This technique is well known for its precision the structures that have been made with the help of this technique completely mimic the targeted structure. The bio ink that is released from the donor side to the receiving substrate is in a controlled manner which results in the intricate and highly précised 3- Dimensional Structure [7].

The nature of this technique is non-contact. It is very good for achieving cell viability. Challenges are still there but researchers are still evolving the field and pushing the boundaries to achieve the desired goals.

4. Stereolithography (STL):

Stereolithography (STL) is a file format used for printing in the process of 3D printing and it plays a vital role as it defines the structure of the targeted object also the layering process is defined by this software. However, you might be referring to Stereolithography (SLA) as a 3D printing technology.

It is the most traditional technology that has been used for many years and is still in use although recent advancements have been considered. It was invented by Chuck Hull in the 1980s and involves using a liquid photopolymer resin that is cured (solidified) layer by layer using an ultraviolet (UV) laser.

Conclusively, we can say that extrusion-based bioprinting, inkjet-based bioprinting, laser-assisted bioprinting, and Stereolithography (SLA) - offer unique capabilities and are driving immense progress in the fields of tissue engineering and regenerative medicine.

Application of Bio 3d Printing Technology:

The bio 3D printing process has a wide range of advancements in the various fields of medical sciences, and it is spreading rapidly as the year passes by. It offers innovative solutions in the fields of tissue engineering and regenerative medicines, drug testing, and disease modelling.

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1. *Tissue Engineering:*
    - ***Purpose:*** To construct the tissues for transplantation and to use in regenerative medicines.
    - ***How:*** Different Techniques of Bio 3D printing enable the adequate placement of cells and bio-inks to construct tissue-like structures, which are used to cure the damaged tissues.
    - ***Example****:* Printing scaffolds for bone regeneration or cartilage repair.
2. *Organ Transplantation:*
    - ***Purpose:*** To make organ Transplantation easier and remove the dependency of the donor.
    - ***How:*** Different Techniques of Bio 3D printing allow the construction of personalized organs with the help of the living cells of the targeted patient[8].
    - ***Example:*** Printing functional liver or kidney structures.
3. *Drug Discovery and Testing:*
    - ***Purpose:*** To construct the model for the drug testing and implementation of the drug.
    - *How:* Different Techniques of Bio 3D printing enable the construction of complex tissue structures that closely mimic the targeted tissue and the physiological environment.
    - ***Example:*** Printing liver tissue for studying drug metabolism.
4. *Disease Modelling:*
    - ***Purpose****:* To study the cause of a particular disease and to identify the optimum treatment for that disease.
    - ***How:*** Bio 3D printing allows researchers to create blueprint models of diseases using patient-specific cells to understand the patient's genetic makeup.
    - ***Example:*** Printing cancer models for studying tumour behaviour.
5. *Wound Healing and Skin Grafts:*
    - ***Purpose:*** To cure wound healing and to promote cartilage treatment.
    - ***How:*** Bio 3D printing can create skin-like structures with integrated blood vessels, improving the success of grafts and enhancing the healing process.
    - ***Example:*** Printing skin grafts for burn victims

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6. *Dental Applications:*
    - ***Purpose:*** To construct customized dental jawbones and tissues.
    - ***How:*** Bio 3D printing is used to create dental structures with precise shapes and functionalities, improving the accuracy and effectiveness of dental procedures.
    - ***Example:*** Printing tooth scaffolds for implantation.
7. *Bioprinting of Food:*
    - ***Purpose:*** To address food sustainability and customize nutritional content.
    - ***How:*** Bio 3D printing is used to create plant-based or cell-based food products with specific textures and Flavors.
    - ***Example:*** Printing plant-based meat alternatives.
8. *Neural Tissue Engineering:*
    - ***Purpose:*** To repair and regenerate neural tissues and promote vascularization.
    - ***How:*** Bio 3D printing can be applied to create neural scaffolds that promote nerve regeneration, potentially aiding in the treatment of spinal cord injuries or neurodegenerative disorders.
    - ***Example:*** Printing neural implants.

As we can see researchers are still evolving the field of 3D bioprinting and Advancements are going on so more applications will come into the picture soon.

Materials and Methods

The Selection of Material in the process of 3D bioprinting Technology plays a vital role. The material which is used in the process is known as bio-inks or hydrogels which are the combination of, adequate biomaterial, supporting material, and living cells. Following are some commonly used biomaterials.

1. *Hydrogels:*
    - **Description:** These materials are rich in water content. These are the water-absorbing polymers and are used to get the hydrated natural tissues. These materials are widely used in the process of Bio 3D printing to construct natural tissue and organs that mimic the structure and environment completely. This provides a hydrated physiological environment to the tissues.
    - **Examples:** Alginate, agarose, gelatine, hyaluronic acid, and fibrin.
2. *Synthetic Polymers:*

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- **Description:** Synthetic polymers are human-made materials that are made by a chain of tissue-like structures and created manually. The biocompatibility of the synthetic polymer is very doubtful as it does not provide adequate biocompatibility with various living cells.

Examples: Polyethylene glycol (PEG), polycaprolactone (PCL), poly (lactic-co-glycolic acid) (PLGA), and polyurethane.

3. *Decellularized Extracellular Matrix (ECM):*
    - **Description:** dECM is extracted from natural tissues that have gone through a decellularization process, removing cellular components while preserving the extracellular matrix (ECM) architecture.
    - **Examples:** Decellularized liver, heart, or other tissue-specific ECM.
4. *Nanocellulose:*
    - **Description:** Nanocellulose extracted from plant sources is part of natural polymers and has gained attention for its biocompatibility and mechanical strength.
    - **Examples:** Nanocellulose derived from wood pulp or bacterial cellulose.
5. *Collagen:*
    - **Description:** Collagen is a major component of the ECM in many tissues and is well-suited for promoting cell adhesion and tissue formation.
    - **Examples:** Type I collagen, often derived from animals or recombinant sources.
6. *Chitosan:*
    - **Description:** Chitosan is extracted from chitin, a natural polysaccharide that can be found in the exoskeletons of crustaceans. It encompasses antimicrobial properties and is biocompatible.
    - **Examples:** Chitosan and its derivatives.
7. *Gelatine Methacrylate (GelMA):*
    - **Description:** GelMA is extracted from gelatin and modified with methacrylic anhydride, allowing for photo-crosslinking during the printing process.
    - **Examples:** Gelatin methacrylate.
8. *Alginates:*
    - **Description:** Alginates are extracted from brown seaweed and have good biocompatibility and gel-forming properties.

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- **Examples:** Sodium alginate.

9. *Silk Fibroin:*
    - **Description:** Silk fibroin is derived from silk and is known for its biocompatibility and mechanical strength.
    - **Examples:** Bombyx mori silk fibroin.
10. *Hyaluronic Acid (HA):*
    - **Description:** HA is a natural component of the ECM and is involved in cell precision and migration.
    - **Examples:** Hyaluronic acid.

Results and Discussion

Bio 3D printing Technology is showing revolutionary results and has attained immense growth, but it still faces some challenges as researchers evolve the field. Vascularisation is still a major challenge in the Field of 3D bioprinting. we will explore the hurdles faced in the realm of bio 3D printing, focusing particularly on the challenges posed by the technology itself and the materials used.

The Complexities of Bio 3D Printing Technology: -

1. ***Precision and Scalability-*** It is difficult to reach well-constructed printed human tissue or organ with the help of Bio 3D printed technology which has a complex architecture. However, 3D bioprinting technology mimics the structure at the macroscopic level, but it is still a challenge to reach the same at the microscopic level.

2. ***Biocompatibility and Cell Viability-*** With the help of 3D Bioprinting technology it is easy to reach the biocompatible structure that has been made using a single cell, but it is still a task for the structure that constitutes various cells. Integration of diverse types of cells in the single bio-ink is still a challenge in the field of 3D bioprinting also it doesn't promote cell viability one cannot rely on the printed structure for a longer period.

3. ***Vascularization and Perfusion-*** The Major challenge in the field of 3D bio printing Technology is vascularization and perfusion. Blood vessel networks the crucial and essential for adequate nutrient and oxygen supply as well as waste removal. However, simulating the intricate architecture and functionality of natural blood vessels remains a complex task. Overcoming this challenge would allow for the fabrication of larger and more complex tissues and organs, enhancing their long-term viability [10].

4. ***Integration of Multiple Cell Types-***While bio 3D printing has made significant strides in fabricating tissues with a single cell type. Integration of the Multiple cells is still a task in the field of 3D bio-printing Technology. It is impossible to attain a

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printed structure that includes multiple cells [11]. It is still a task to fabricate a network of blood vessels or tissues.

The Materials Challenges in Bio 3D Printing: -

1. ***Selection and Development of Bioinks-*** Bioinks are the most important part of the 3D bioprinting technology and play a vital role in the fabrication of the targeted tissues and the organs that are in use of organ Transplant and tissue engineering also in the field of regenerative medicine. To reduce the risk of rejection of organ it is important to select the appropriate material for the biocompatibility, mechanical strength, bio functionality, and viability. The major challenge is that bio-inks are extremely limited and cannot support various cell types. Developing novel bio-inks that can mimic the complexity and characteristics of native tissues is an ongoing research endeavor [12].

2. ***Sterility and Contamination-***It is Essential to maintain the sterility of the bio-ink and to avoid contamination in the bio-ink as a single contaminant can impact the characteristics of the bio-ink and which will not be comparable with the characteristics of the targeted tissue and organ. Contamination of the bio-ink is affected by the temperature, pH, and the environment so it is necessary to protect the bio-ink while performing the process.

3. ***Mechanical Strength and Long-Term Stability-***For the successful integration of the printed structure it is necessary to have long-term stability and adequate mechanical strength. The materials used in bio 3D printing should supply the necessary support and mimic the mechanical properties of native tissues [13]. However, achieving the desired strength and stability is still a challenge, especially when printing larger or more complex structures. Improvements in material properties, such as tensile strength and durability, are necessary to ensure the functional and structural integrity of the bio 3D printed constructs.

Conclusion

In the fields of tissue engineering, reproductive medicine, and customized health care, bio 3d printing plays a vital role in human life. The combination of different advanced techniques and selected materials has pushed the field of biomedical very innovative. The wide range of 3d printing techniques, including extrusion-based printing, inkjet-based printing, stereolithography, selective laser sintering, and bioprinting with microfluidics, give us an adaptable tool to define various challenges in the development of complex and purposeful biological structures,

Although the 3d bio-printing techniques give the promise to transform the medical field various challenges endure [14]. The difficulties of bioprinting techniques, such as accuracy, scalability, and vascularization, petition ongoing study and innovation. Additionally, the selection and the regeneration of various bio-inks and hydrogels are giving the mechanical properties hurdles, by addressing the challenges, we can take the potential of bioprinting technology, transforming health by developing the

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functional tissue and organ. The selection of appropriate materials, often referred to as bio-inks, is essential to the success of bio-3D printing. Hydrogels, synthetic polymers, decellularized extracellular matrix, nitrocellulose, collagen, chitosan, gelatine methacrylate, alginates, silk fibroin, and hyaluronic acid are among the key materials that offer unique properties catering to the specific requirements of different tissues and applications. These materials provide the foundation for the intricate scaffolds that support cell growth, differentiation, and the development of functional tissues. While immense progress has been made, challenges are going on, including achieving vascularization within printed tissues, ensuring long-term cell viability, and directing ethical considerations. Recent research is focusing on overcoming the hurdles and further refining bio 3d printing technologies[15].

Bio 3D printing is confined to the connection of technology and biology, offering a glimpse into a future where the borderline of what is in medical science is continually expanded and redefined.

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RECENT ADVANCEMENT IN SOLARSTILL TECHNOLOGIES: A REVIEW

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Abstract
Nowadays, some countries facing crises related to water shortage in some areas. To achieve sixth development goal from seventeen Sustainable Development Goals (SDGs) which is related to clean water and sanitation, solar still is one of the best device to provide drinkable water after converting from brackish water. However, low rate of production of solar still are major drawback. But in recent years, researchers, scientists and engineers are investigating the optimum method for enhancing the production rate of solar still. This review paper highlights the efforts of researchers in the field of advancing the solar still technology.

Keywords
Solar still, production rate, thermal efficiency, active solar still, passive solar still etc.

Introduction
The world's population has been growing quickly during the last few years. According to statistics, it is reached from 6.143 billion in 2000 to 8 billion people in 2022 which results in increasing rate of 30.2% in this period. **[1]** emphasis that with increase in number of people definitely increase in the demands of basic needs mainly food, water, cloth, shelter, education etc. which results in increasing the standard of living. Water is one of the most essential components for all living beings. We cannot imagine a life without water for small period of time. Even life exists on earth because of water availability along with the other essential components also. According to **[2]** water is one of the basic building blocks to sustain life on this planet. But rapid increase in population and increase in demands of organic agricultural products, the demand of water drastically increasing. Desalination of brackish water is considered to be an ideal tool against the scarcity of water. For sustainable and economic development, availability of fresh water is very important. According to **[3]** due to rapid increase in population and modernization, the demand of fresh water increases drastically. Water available in rivers, sea, ponds and lakes is not readily able to use. It must be purify through some process to obtain potable water.

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Water scarcity is indeed a significant global challenge with far-reaching implications for human societies, ecosystems, and overall sustainable development. **[4]** highlights the several factors contribute to water scarcity, including population growth, climate change, inefficient water use, pollution, and inadequate water management practices. As the world population rapidly increases and urbanize. **[5]** states that by 2025, it is anticipated that two-third of the world's population would live in countries where fresh water is in low supply and at the end of 2030; fifty percent of world population will be affected by the high water stress problem. There is a severe fresh water shortage in many nations throughout the globe, especially in developing nations and some regions in the Middle East.

Solar distillation is the method of separating brackish water using solar radiation. Since it employs sunlight directly from sun to heat the brackish water and collect the condensate water as pure water through proper channel, it is one of the most significant water purifying technologies. Solar still are the equipment used for solar distillation process. **[6]** stated that the basic idea of solar still consist of an airtight container of salty water that is heated by sunlight from sun which causes it to evaporate, afterthat water vapor condenses on an inclined glass surface, allowing clean water to flow into a pure watertank. **[7]** highlights the numbers of methods used for purification of water including filtration, disinfection, sedimentation and distillation.**[8]** the process of discharging pollutants from large-scale seawater desalination plants probably involves substantial energy usage. According to **[9]** total of 203 million tonne of oil are thought to be needed annually to produce 22 million m^3 of fresh water every day. Thus there is a need for continuous research related to improvement in design of solar still. **[10]**emphasizes on possible ways to distill impure water using renewable energy sources like solar, wind, tidal etc. due to its accessibility sound, cost-effective and energy potential. According to **[11]**core concept of solar still consist of an airtight container of salty water is heated by sunlight from sun which cause water to get evaporate. As water evaporates, vapors get generated. After that water vapor allows to cool down on an incline glass surface and undergoes condensation process allowing clean water to flow into a pure water tank. Water is distilled to remove pollutants so that only pure water vapour remains making the water safe to drink. [**12]** analysed how solar stills are helpful in providing water free from inorganic, bacterial, organic non-volatile pollutants and bacteria. **[13]** enlisted the benefits of solar still, its ability to produce numerous liters of water per square meter of still each day for an affordable initial investment. According to **[14]** the high volume heating system creates vapor on the upper water and solar thermal conversion occurs at a solar receiver near to the large bulk water body This review paper discussed about the new advancement made in solar still design in recent period. The effect of various devices such as reflectors, Phase Change Material (PCM), stepped absorber plate PV panel etc. has been discussed.

Literature Review

[15] aimed to address multiple aspects of solar still operation, including heating of feed water, maximizing solar energy absorption, and enhancing thermal energy management. This comprehensive approach likely resulted in significant improvements in the performance and

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efficiency of the solar still system, making it more viable for practical applications in water desalination or purification. The higher temperature of the feed water is expected to result in quicker evaporation. Internal reflectors are often used in solar devices to enhance the concentration of sunlight onto the absorbing surface, thus increasing the overall efficiency. PCM beds are known for their ability to store and release thermal energy, potentially improving the overall efficiency of the solar still. Experimental setup used in this experiment was shown in **Fig. 1.**



Fig. 1. Modified Solar Still

[16] conducted a study to evaluate the performance of traditional solar still units with various modifications aimed at enhancing productivity. Two main modifications were investigated: the incorporation of evacuated tube collectors and the addition of parabolic trough reflectors. The key findings of the study suggest that combining both modifications leads to more significant improvements compared to using each modification separately. Specifically, when the traditional solar still unit was equipped solely with evacuated tube collectors, there was an 82.26% increase in productivity compared to the unmodified unit. This indicates that evacuated tube collectors alone have a considerable positive impact on productivity by enhancing heat input to the system. However, the study found that the most substantial improvement in productivity occurred when both modifications—evacuated tube collectors and parabolic trough reflectors—were used simultaneously. In this combined configuration, there was a remarkable 112.57% increase in productivity compared to the unmodified unit. This suggests that the synergistic effects of using both evacuated tube collectors and parabolic trough reflectors result in significantly greater enhancements in productivity than when either modification is applied alone. The experimental setup used in this experiment was shown in **Fig. 2.** This is a crucial aspect as it highlights the practical implications and economic feasibility of the proposed modifications.

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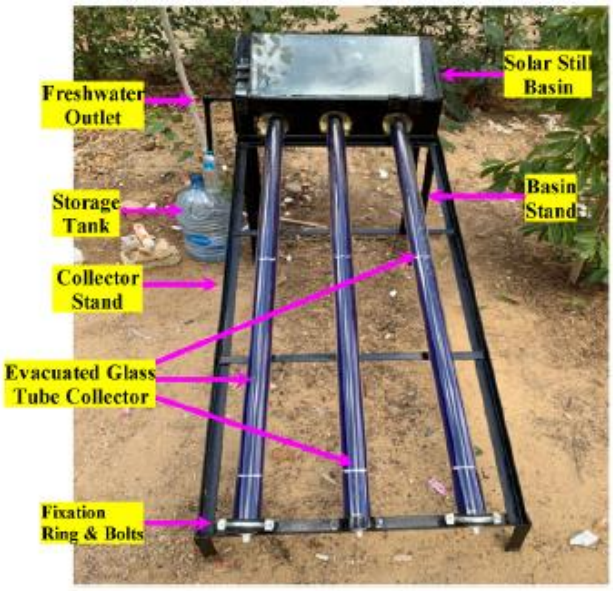


Fig. 2. Experimental set up used in the experiment

[17] conducted a study comparing the performance of Cylindrical Sector Solar Stills (CSSS) with Double-Slope Solar Stills (DSSS). The research aimed to evaluate the productivity and thermal efficiency of both types of solar stills under specific conditions. The key findings of the study indicate that CSSS outperformed DSSS in terms of productivity and thermal efficiency. Specifically, the accumulated productivities of CSSS and DSSS, both utilizing black fiber and black dye, were 3514 ml/m² and 3029 ml/m², respectively. This represents a 16.01% increase in productivity for CSSS compared to DSSS. Additionally, the daily thermal efficiencies of CSSS and DSSS, using the same materials, were 30.42% and 26.32%, respectively. CSSS exhibited a 15.58% increase in thermal efficiency compared to DSSS. The study suggests that the integration of cost-effective materials, such as black fiber and black dye, contributed not only to improved performance but also to economic advantages. CSSS demonstrated a lower cost per liter compared to DSSS, further highlighting its potential as a more efficient and economically viable option for freshwater production in solar desalination systems. The comparison between CSSS and DSSS, along with the utilization of specific materials, provides valuable insights into optimizing solar desalination systems for enhanced performance and cost-effectiveness. These findings contribute to the ongoing efforts to develop sustainable solutions for freshwater production, particularly in regions where access to clean water is limited. The CSSS and DSSS used in this experiment was shown in **Fig. 3.**

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Fig. 3 CSSS and DSSS used in this experiment

[18] conducted a study focusing on a dual-slope solar still integrated with a mild hybrid power supply system as a potential solution to global freshwater scarcity. The research explored various power supply configurations and the incorporation of phase change materials to improve system performance. The study reported positive results in terms of freshwater production rates, with the dual-slope solar still achieving up to 6.76 liters per square meter per day (l/m²d). The implementation of mild hybrid technology in the solar stills led to higher freshwater production rates, achieving an efficiency of 37%. It was observed that productivity in the hybrid mode was at least twice as high as in the passive mode. Despite the benefits of using phase change materials in terms of heat retention, the study noted that it did not lead to a reduction in the cost of freshwater production. However, the integration of mild hybrid power supply systems was deemed technically and economically viable. This suggests that the hybridization of dual-slope solar stills with mild hybrid power supply systems is a promising approach for addressing freshwater scarcity. The experimental setup used in the study, as depicted in **Fig. 4** provided insights into the configuration and operation of the hybrid solar still system. By demonstrating the effectiveness of hybridization in improving freshwater production rates, the study contributes to the ongoing efforts to develop sustainable solutions for addressing water scarcity challenges globally.

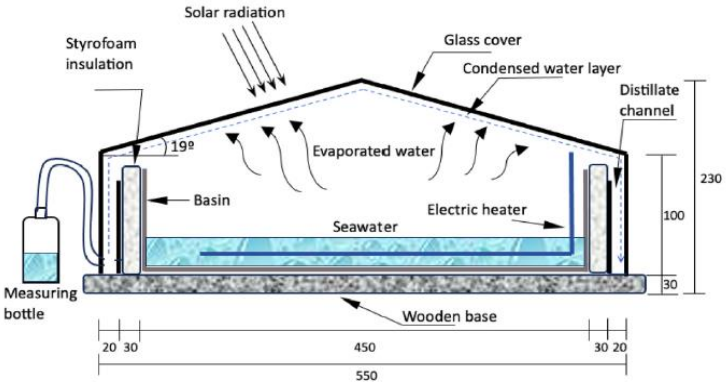


Fig. 4. Experimental setup used in this experiment (All dimensions are in mm)

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[19] conducted research on trapezoidal pyramid solar stills to investigate their production rate and thermal efficiency under different modifications. The study aimed to enhance the performance of the solar stills through various modifications and evaluate their effectiveness in water production and thermal efficiency. The experiments were conducted under the climatic conditions of Kafrelsheikh City, Egypt. A wick material was placed in the basin area of the trapezoidal pyramid solar still to facilitate water transport and enhance evaporation. A cooling unit was incorporated into the solar still system to boost the condensation rate, thereby increasing freshwater production. Reflectors were placed opposite to each side of the glass cover to concentrate solar radiation onto the evaporation surface, thereby increasing the energy input to the system. A cooling cover unit was used to enhance both evaporation and condensation rates, contributing to higher productivity and thermal efficiency. CuO-based nanofluid was employed as an energy storage material to increase the thermo-physical properties of water, leading to improved heat transfer and enhanced evaporation and condensation rates. The results obtained from the experiments indicated that all the modified cases demonstrated higher production rates and thermal efficiencies compared to conventional solar stills. However, the fifth case, utilizing CuO-based nanofluid as an energy storage material, exhibited the highest enhancement in productivity and thermal efficiency among all the cases tested. The photographic view of the experimental setup, as shown in **Fig. 5** provided a visual representation of the implemented modifications and their configuration within the solar still system. Overall, the findings of the study highlight the potential of these modifications to significantly improve the performance of trapezoidal pyramid solar stills, thereby contributing to more efficient and effective freshwater production in regions with water scarcity.

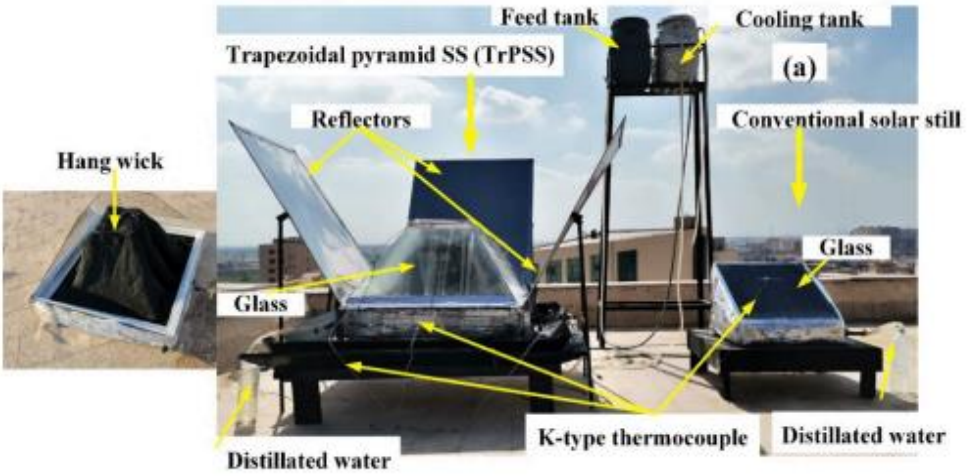


Fig. 5. Photographic view of experimental steup

[20] conducted research aimed at enhancing the productivity of solar stills using a novel approach involving the incorporation of cotton bags filled with phosphate pellets as thermal energy storage material. The study focused on comparing the performance of conventional solar

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stills with modified versions incorporating the innovative thermal energy storage system. The experimental setup involved three cases:

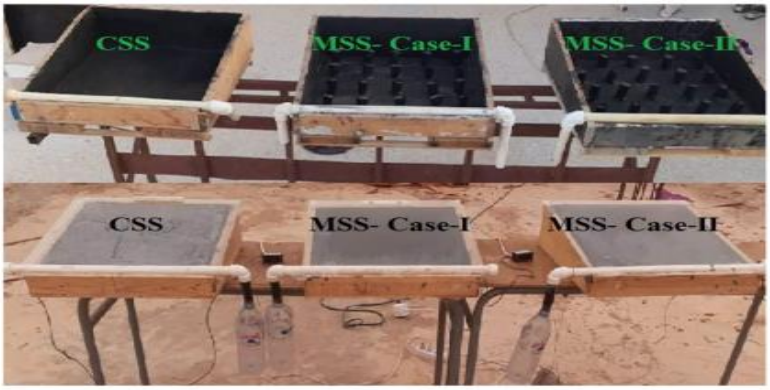
Conventional Solar Still: This served as the baseline for comparison.

Modified Solar Still (MSS) Case I: In this configuration, 25 bags of cotton, each in cylindrical shape with a diameter and length of 4 cm, were placed vertically in the basin. These bags were filled with phosphate pellets for thermal energy storage. Additionally, the basin contained 2.5 kg of saltwater up to a water depth of 1 cm.

Modified Solar Still (MSS) Case II: Similar to Case I, this configuration included 25 cotton bags filled with phosphate pellets. However, the amount of saltwater in the basin was increased to 5 kg, filling it up to a water depth of 2 cm.

The arrangement of cotton bags containing phosphate pellets in the basin is illustrated in **Fig. 6(a)** while the three experimental setups are depicted in **Fig. 6(b)**. During the three-day experiment, the researchers observed the performance of each setup. The results indicated that the inclusion of phosphate-filled cotton bags as energy storage material led to enhancements in both thermal efficiency and water production rate compared to the conventional solar still. Furthermore, MSS Case I demonstrated a higher production rate compared to MSS Case II. This difference was attributed to the lower water depth in Case I, which allowed for quicker evaporation compared to the higher water depth in Case II. Overall, the findings of the experiment underscored the effectiveness of using phosphate-filled cotton bags as thermal energy storage material in enhancing the performance of solar stills. The study provides valuable insights into innovative approaches for improving the efficiency and productivity of solar-driven desalination systems, which could have significant implications for addressing water scarcity challenges in arid regions.





(a) **(b)**

Fig. 6(a) arrangement of cotton bags containing phosphate; (b) three cases of experiments

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Conclusion

Based on the efforts made by researchers in the field of solar still in above experimental work weather the modification made in design of solar still or addition of external device will always be fruitful regarding solar still improvement when it comes to productivity and efficiency. From the literature review following conclusions were made as follows:

- Future research should explore the incorporation of various nanoparticles with phase change materials (PCM) beneath the basin. This could lead to improvements in yield rate, thermal properties, heat transfer characteristics, and continuous freshwater production, even during the night.
- By incorporating thermal energy storage materials, such as phase change materials or thermal mass, solar stills can continue to operate and produce distilled water even during periods of reduced sunlight or at night. This enables a more consistent and reliable water production process, ultimately improving overall efficiency.
- Combining different solar still designs is suggested as a method to enhance the efficiency of modified solar still systems. By integrating elements from multiple designs, such as incorporating reflectors to concentrate sunlight onto the evaporator surface or using multiple-effect distillation configurations, researchers aim to optimize the performance of solar stills.
- Integrating a solar still with a greenhouse-type structure has been shown to result in higher distilled water output compared to conventional solar still types. The greenhouse structure provides additional benefits such as trapping solar radiation, creating a warmer environment conducive to evaporation, and reducing heat loss during nighttime or adverse weather conditions. This integration enhances the overall efficiency of the solar still by optimizing environmental conditions for water vapor generation and condensation, ultimately leading to increased freshwater production.

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Design of E- Vehicle Charging system using Renewable PV-Wind Resources in Residential Environments

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Abstract

The main aim of the work is to design a prototype model to charge an Electrical Vehicle (EV) using renewable energy sources such as Photovoltaic (PV) and wind energy. For this purpose, a Vertical Axis Wind Turbine (VAWT) with rated power capacity of (2kW, 24volts) and PV panel with (0.2kWp, 24 Volts) are connected with a separate 24V, charge controller to avoid voltage fluctuation and reverse conduction during charging. This work is to design a renewable power charging capacity of 2.2kW at 24V to charge a battery potential at 24V .The Battery of the EV can charge at 72V, 26Ah with the total charging time of 8hr and 12 minutes with a three sets of 24V battery string connected in series to give 42Ah. This arrangement can charge EV battery with renewable energy and can give no energy cost spending, pollution free energy with reducing carbon emissions for the increased EV energy with the increased EV energy demand in near future from these sustainable resources.

Keywords: Electrical Vehicles (EVs), Vertical Axis Wind Turbine (VAWT), PV panel, PV Charge controller.

I. INTRODUCTION

A vehicle classified as an electric vehicle (EV) operates through the use of an electric motor, as opposed to an internal combustion engine that generates power by burning a combination of fuel and gases. The term "EV" is an abbreviated form referring to an electric vehicle, which can be either partially or fully powered by electric energy. Electric vehicles are known for their cost-effectiveness due to fewer moving parts required for maintaining torque [1], and they are also recognized for their environmentally friendly nature.

Typically, electric vehicles minimize or completely eliminate the use of fossil fuels such as petrol or diesel. The adoption of renewable energy sources to fuel EV charging infrastructure not only alleviates the strain on the grid but also contributes to environmental sustainability, particularly when coupled with intelligent EV technologies. The essential findings of pertinent literature related to this proposed work are presented in Table-1.

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Table-1 Literature survey

Authors	Journal title	Inference
Ahmad A. Pesaran and Tony Markel, Harshad S. Tataria, David Howell.	Battery Requirements for Plug-In Hybrid Electric Vehicles Analysis and Rationale National Renewable Energy Laboratory, USA, (2009).	Over the next 10 to 20 years, PHEVs hold the promise of substantially reducing the reliance on petroleum. The primary impediments hindering the widespread commercialization of PHEVs revolve around concerns related to the cost, safety, and lifespan of batteries[1]
Choe, G.Y., Kim, J.S. and Lee, B.K.	A Bi-directional battery charger for electric vehicles using photovoltaic PCS systems. IEEE Vehicle Power Propels Conf. IEEE, pp. 1-6, (2010).	A novel idea is introduced for a bidirectional battery charger designed for PHEV and EV, incorporating a photovoltaic generation system and an operational algorithm for the battery charging system[2].
Thirugnanam, K., Ezhil Reena, JTP. Singh, M. and Kumar, P.	Mathematical modeling of Li-ion battery using genetic algorithm approach for V2G applications. IEEE Trans. Energy. 29: 332-43, (2014)	This paper introduces a battery model based on electric circuits and a capacity fade model for EVs in applications involving V2G scenarios[3].
Li Wang	Design of electric vehicle charging station based on wind and solar complementary power supply, AIP Conference Proceedings, (2018)	Design of wind power generation system and the selection of wind turbine[4].
Yu Yang, Qing-Shan	Decentralized EV-based charging optimization with building integrated wind energy, IEEE Trans. Automation science and Engineering Vol.16, (2019)	This journal article elucidates the significance of EV charging utilizing locally generated wind power from buildings, which has the potential to alleviate the effects of EV demand on the power grid. [5].

FUNCTIONAL BLOCK DIAGRAM

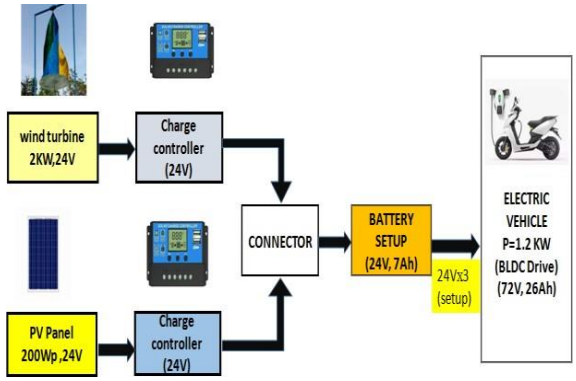


Figure 1. Block diagram

An efficient involute type[6] vertical axis wind turbine (2kW) used in urban area is connected with permanent magnet DC generator (0.5kW) to convert wind energy and this output is connected to a 12V charge controller[7]. Similarly, a PV panel (200Wp, 24V) is connected to another 12V charge controller, as shown in Figure 1. These two Renewable energy source both are parallel connected to a common connector 24V to the battery (24V, 7Ah). A 24V×3 Setup battery is connected in series charge on Electric Vehicle (72V,26Ah) in a energy efficient, reliable BLDC motor drive with power 1.2kW[8]. This hardware model is shown in Figure 2. With a charge controller and its rated values are mentioned in Table 2 & Table 3.



Figure 2. Wind & PV Sources with controller

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II. DESIGN OF VAWT- PV HYBRID SYSTEM

In the case of Vertical Axis Wind Turbines (VAWT), the efficiency of receiving effects during blade rotation surpasses that of Horizontal Axis Wind Turbines (HAWT). This superiority is attributed to the consistent stability of the inertial force and gravity directions, coupled with the relatively confined space for blade rotation. Consequently, VAWT blades experience a constant load, leading to a higher power utilization of 20% compared to HAWT. VAWT also boasts simplicity in installation and maintenance when contrasted with HAWT. The placement of the vertical axis wind turbine beneath the rotor or on the ground facilitates easy repair and maintenance, resulting in a lower failure rate and absence of cable standing issues. The tip speed ratio for vertical axis wind turbines typically ranges from 1.5 to 2, significantly lower than that of the horizontal model. This lower rotational speed inherently avoids the generation of aerodynamic noise. As a result, the noise level of VAWT remains below 40dB at distances less than 20ft / 6m.

Table 2 VAWT Model Ratings

Max.Power Rating	2kW
Voltage	24V
Minimum Speed	2m/s
Maximum Speed	24m/s
Average Wind Speed	6-12m/s

The impact on avian species is diminished VAWT due to their lower rotational speed. A photovoltaic module, or solar panel, constitutes a packaged interconnected assembly of photovoltaic cells, commonly known as solar cells. This solar panel serves as a crucial component in larger photovoltaic systems designed to generate electricity for both commercial and residential applications [4]. The principal challenge associated with solar power, as well as its counterpart wind power, lies in their efficiency. The Earth receives an ample amount of energy in the form of solar radiation, surpassing the power requirements of our species. Estimates indicate that the available wind energy is four times greater than the annual energy consumption of the entire species. Solar power, too, presents a remarkable abundance, as the sun showers the planet with more energy daily than our annual consumption. Thus, the fundamental challenge has never been the scarcity of sunlight and wind; both are readily accessible[9].

Table 3 PV model Ratings

Maximum power (P max)	200 Wp
Open circuit voltage (Voc)	24 V
Max current rating (Isc)	5A

A comprehensive investigation into the integration of electric vehicles (EVs) and photovoltaic generation (PV) has been conducted, resulting in satisfactory performance outcomes[10]. The study employed a linear optimization model to assess the impact on the energy system, encompassing design criteria, setup procedures, control strategies, and experimental tests tailored for a DC micro-grid power configuration facilitating the rapid charging of fully electric and plug-in hybrid vehicles. The proposed charging architecture was formulated based on an analysis comparing key characteristics of established architectures. The scrutiny of the proposed power conversion architecture emphasized the evaluation of charging/discharging power, efficiency, energy flux management, and its implications for the main grid. Furthermore, the study involved the assessment and implementation of effective control strategies, enabling the proposed architecture to adhere to requisite operations, as depicted in Figure 3. Utilizing renewable energy systems for the operation of electric vehicles represents an environmentally friendly technology[11][12]. A DC link voltage sensing-based smart charging station was developed specifically for Plug-in Hybrid Electric Vehicles (PHEVs).

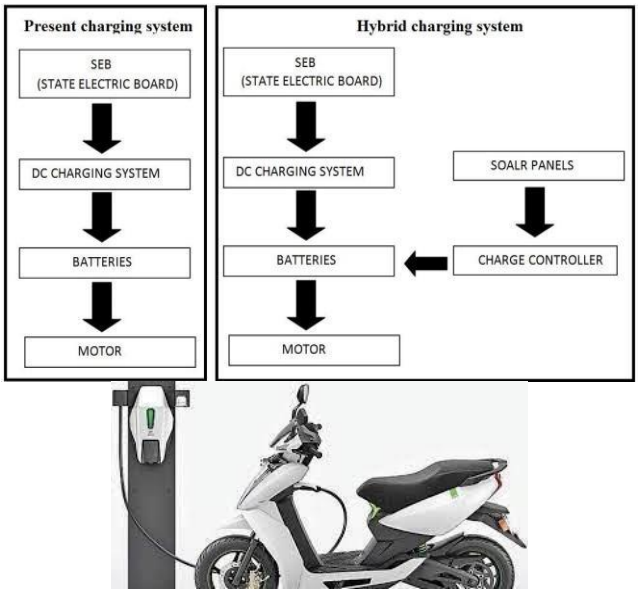
and a MY1016Z2 BLDC motor controller with gear reduction and it is a unique invention for this type of applications. This is why this design takes pride in introducing the 24 Volt, 250 Watts, MY1016Z2 gear reduction motor, complete with a 9-tooth 1/8" bicycle chain sprocket. This motor is ideal for individuals looking to build their own custom electric vehicle, be it a scooter, electric bicycle, tricycle, or something groundbreaking that the world may not be prepared for yet. Distinguished by its gear reduction feature, this electric motor delivers lower-end torque compared to conventional motors. The circuit diagram for 12V battery connections, along with suitable charge controllers, is illustrated in Figure 5. Additionally, Table 3 provides cost estimation for a Vertical Axis Wind Turbine (VAWT) and Photovoltaic (PV) model setup designed for an electric vehicle charging model.

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Figure 3. EV Charging Model



IV. E-BIKE HARDWARE COMPONENTS



Figure 4. EV Testing Model with battery

Figure 4 shows the Key Features 24 volt, 250 watts, 9 tooth, 1/8" bicycle chain sprocket.

Figure 5. Circuit Diagram

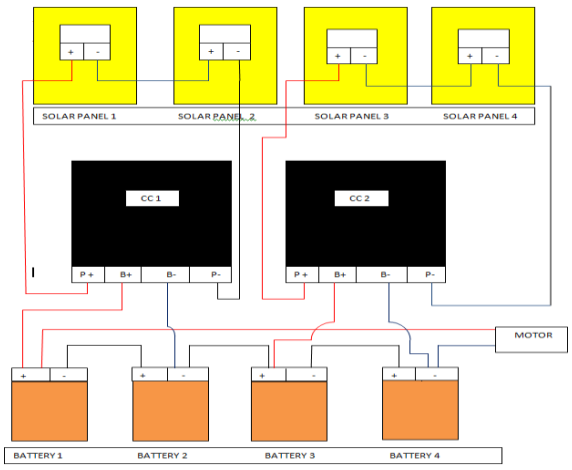


Table 4 Cost Estimation

Components	Rating	Size	Cost (Rs)
Vertical axis wind turbine(2KW),PMDC generator, gear setup, bearing	Rated speed 1500RPM, Rate d voltage 24V	1	15000
PV Solar panel (200Wp)	Rated voltage 24V	1	10000
Charge controller	Rated voltage 24V	2	2500
Battery (Lead Acid)	Rated Voltage 12V,7Ah	2	2000
Total Cost (Rs)			29500

V. CONCLUSSION

Total energy capacity 2.2kW approximately for 4hrs can give 8units. Electric bike needs 5 units for fully charging and can give 100km/charge. The excess of units from this wind solar energy sources can also be consumed for home appliances with suitable inverter. Wind energy stands out as the most rapidly expanding renewable energy source. The growth of the wind energy industry has been propelled by market incentives supported by government policies aimed at fostering sustainable energy resources.

With large-scale wind facilities approaching the output levels of conventional power plants, ensuring control over power quality becomes imperative to mitigate adverse effects on their seamless integration into the network. Concurrently, the increasing popularity of electrical vehicle manufacturing is anticipated to lead to a substantial rise in its market share. The cost-effectiveness of electric vehicles, being 75-80% cheaper in terms of both fuel and maintenance, is a significant consideration for many consumers with high usage patterns.

Future scope: E-Bicycle design with features such as on-load PV charging with regenerative breaking application, provided at minimum cost, (Project work).

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ISFT EE - 21
Assessment of Dual and Multi level Security Mechanisms

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Abstract: As the number of internet users continues to rise, the secure transmission of confidential information has become a crucial necessity for various applications, including medical, education, and business transactions. In this context, the demand for an adept protection mechanism is evident.The widespread solutions are cryptography and steganography. The former method changes data into the form comprehensible only by the intentional users, and in later mechanisms, data is concealed in an envelope for safety. While cryptography and steganography are valuable tools, each has its limitations. In the case of cryptography, a significant drawback arises when an intruder gains access to the cryptographic key, enabling them to easily decrypt the message.In steganography, if the intruder suspects the subsistence of a message, then the secret data exposure is relatively easy. Thus, a dual/ multi level approach is preferred instead of a stand-alone technique to provide added security to the confidential data. The information security mechanism designed to ensure secure communication must fulfill the following critical requirements; confidentiality, authenticity, integrity, reproducibility, randomness, and optimized implementation time. This paper is committed to review such techniques, which can accomplish all these requisites. A wide range of existing multi-level algorithms are studied and implemented based on defined performance parameters.

Keywords: Authenticity, Confidentiality, Dual/multi level security mechanisms, Performance parameters, Steganography.

1.1. Introduction

In the domain of security, dual or multi-layer security mechanisms amalgamate two distinct protective measures or employ identical cascading methods to fortify the defense of confidential information. The surge in security threats mandates the fusion of these techniques, as standalone algorithms exhibit limitations in providing security beyond a specific threshold. Drawing upon existing integrations, the addition of multiple layers, each consisting of appropriately chosen security mechanisms, establishes the groundwork for a highly protected system.This imperative highlights the incorporation of multiple layers to construct a robust and comprehensive security architecture; this is the stimulus behind adding multiple layers to form a highly secure system. Furthermore, a blending of two methods endows with a better shield than the single layer of security, as demonstrated by various researchers [1-6]. Still, strengthening in safety threats prompts programmers to improve defence by combining methodologies in more sophisticated ways, as illustrated next.

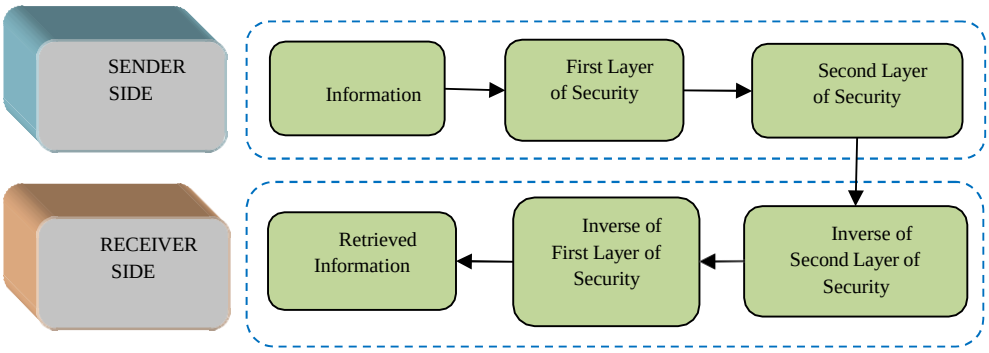


Figure 1.1 General structure of dual-level security mechanism

Figure 1.1 illustrates the overall structure of the dual-level security mechanism. It consists of a twin level of protection for information to be secured. In most of the available hybrid techniques, cryptography constitutes the first layer of security, and steganography forms another stage to provide intact protection to the information to be hidden. However, there are mechanisms in which both layers are comprised of encryption algorithms. The remainder of the paper is organized as follows; Section 1.2shows brief description of dual level mechanisms available in literature. Section 1.3 gives comparison of implemented mechanisms on the basis of defined performance parameters. Section 1.4 elaborated diverse multi level security mechanism followed by section 1.5,

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in which these stated techniques are compared on the basis of illustrated parameters. Finally, section 1.6 provides conclusion followed by references.

1.2. Dual/twin level Security Mechanism

Figure 1.2 shows diverse dual layer mechanisms taken for studies and execution.

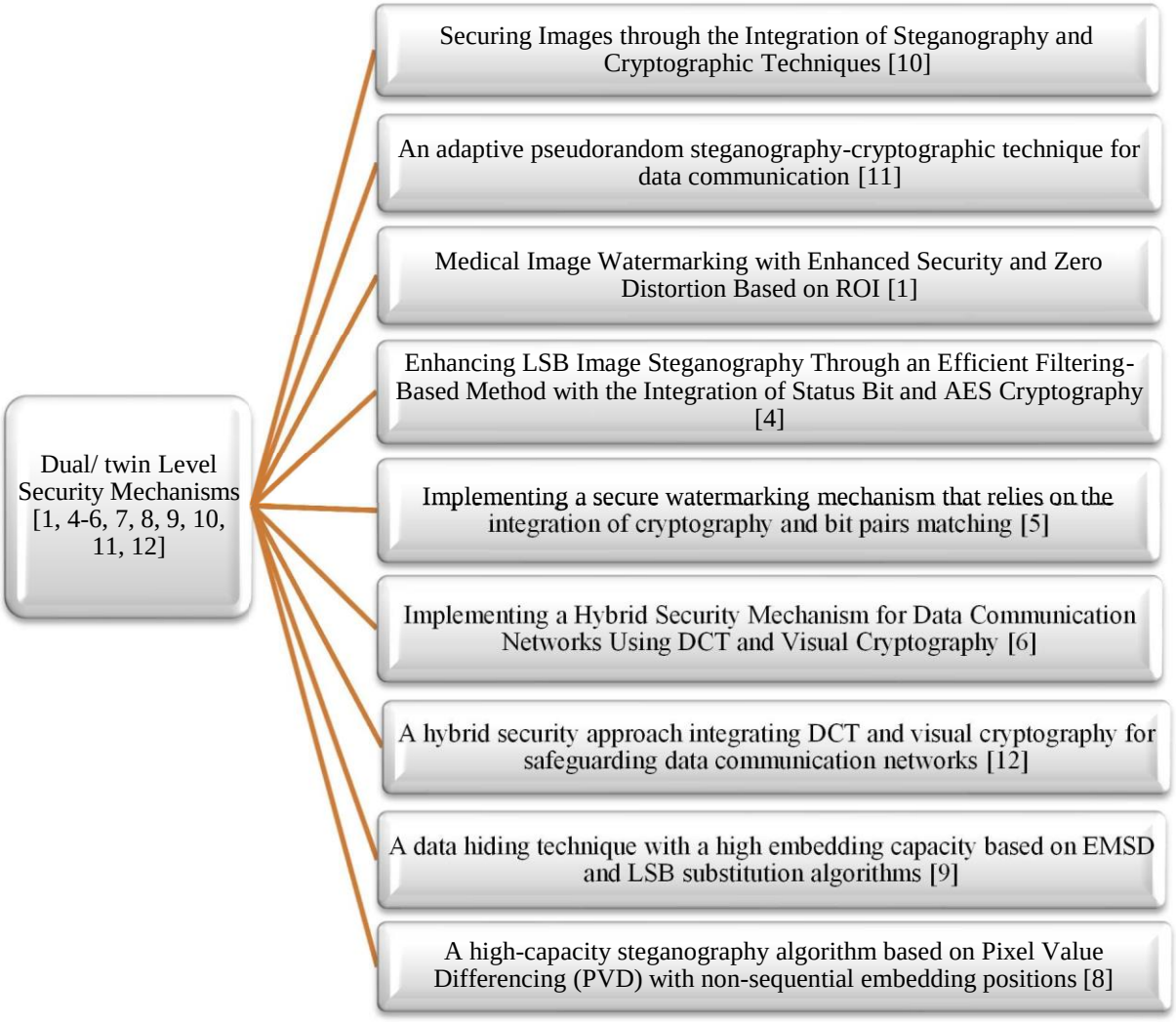


Figure 1.2 Dual-level security mechanisms

1.2.1. Securing Images through the Integration of Steganography and Cryptographic Techniques [10]

In this scheme, the hybrid approach involves the cascading integration of cryptography and steganography techniques.

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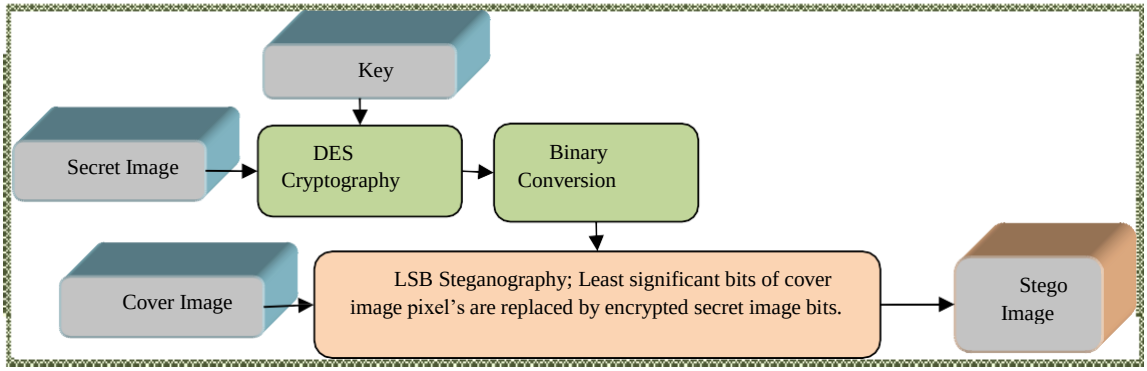


Figure 1.3 Image security using steganography and cryptographic techniques

Figure 1.3 illustrates the block diagram providing an overview of the presented scheme. The Data Encryption Standard (DES) is employed for encrypting secret images, and the Least Significant Bit (LSB) mechanism is utilized for concealing the encrypted secret images within the cover image. The first step of security isencryption accomplished by the DES algorithm, which transforms the plain text into ciphertext. The LSB substitution steganography mechanism constitutes the second layer of security.

1.2.2. An adaptive pseudorandom steganography-cryptographic technique for data communication [11]

The given mechanism is an adaptive method taking care of problems encountered in information security. Figure 1.4 shows the block diagram showing insight into the given scheme. It unites the stream cipher cryptographic technique with a modified pseudorandom LSB substitution technique to provide even distribution of ciphertext. [11]. The first layer of security is the encryption mechanism used for the plain text to be transferred. This text is encrypted using function RC4 algorithm using a key. The text that has undergone encryption is expressed in the form of a bit-stream. The foremost step of the mechanism is to identify the pixels of the cover image where the ciphertext bits are to be stored. The exact process is followed for both the sender and receiver. To accomplish this, a Pixel Position Number (PPN) array is calculated in which each element indicates a distinctive pixel in the cover image. To retrieve an encrypted message, the recipient must possess both the seed and the length of the message to pinpoint the embedded pixels in the stego-image. Furthermore, the decryption key is required to decipher the message. All PPN are generated in the same way as the sender side. The LSBs of these pixels are retrieved as data and further decrypted using the reverse RC4 algorithm to obtain an original secret text.

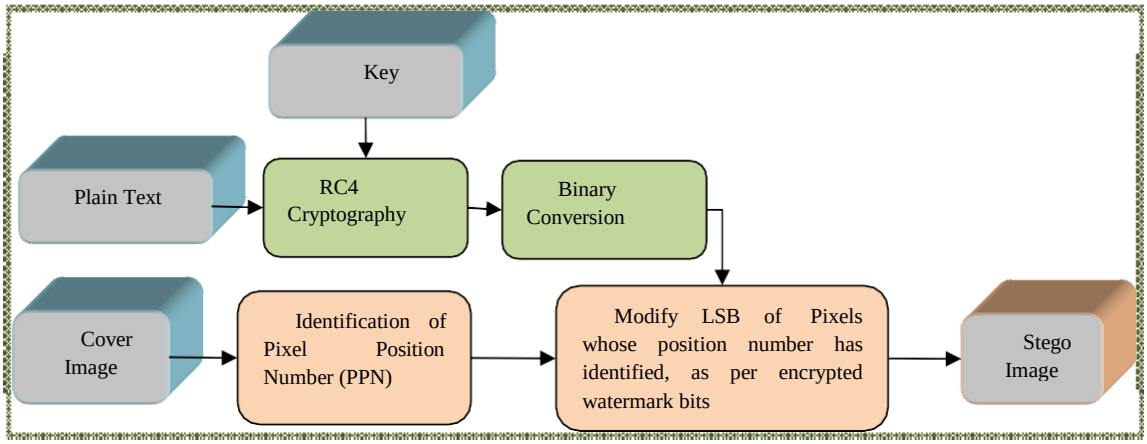


Figure 1.4 An adaptive pseudo-random stego-crypto technique

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1.2.3. Medical Image Watermarking with Zero Distortion and Enhanced Security Based on Region of Interest (ROI) [1]

This dual-stage mechanism consists of RSA encryption followed by DWT Steganography [1].

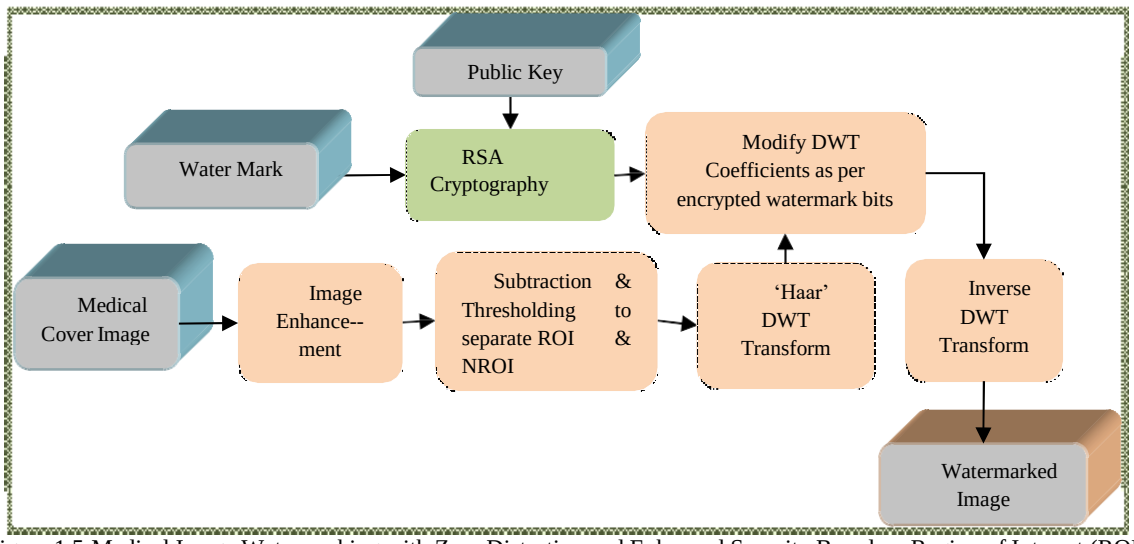


Figure 1.5 Medical Image Watermarking with Zero Distortion and Enhanced Security Based on Region of Interest (ROI)

Figure 1.5 Illustrates the block diagram providing an overview of the proposed scheme. This dual-stage mechanism combines medical image watermarking and encryption. The RSA cryptography algorithm is applied to encrypt the watermark, and subsequently, it is embedded into the Discrete Wavelet Transform (DWT) coefficients of the medical image. To extract the concealed message, the reverse order of processes is followed.

1.2.4. Enhancing LSB Image Steganography Through an Efficient Filtering-Based Method with the Integration of Status Bit and AES Cryptography [4]

[4], Dual-layer security is implemented through a two-fold process. Initially, the secret message undergoes encryption, transforming it into ciphertext using the AES algorithm. Subsequently, the ciphertext is concealed within the cover image utilizing an innovative Steganography technique designed to accommodate substantial data within the cover image. This novel approach incorporates status checking during the embedding and retrieval phases of information, enhancing overall security.

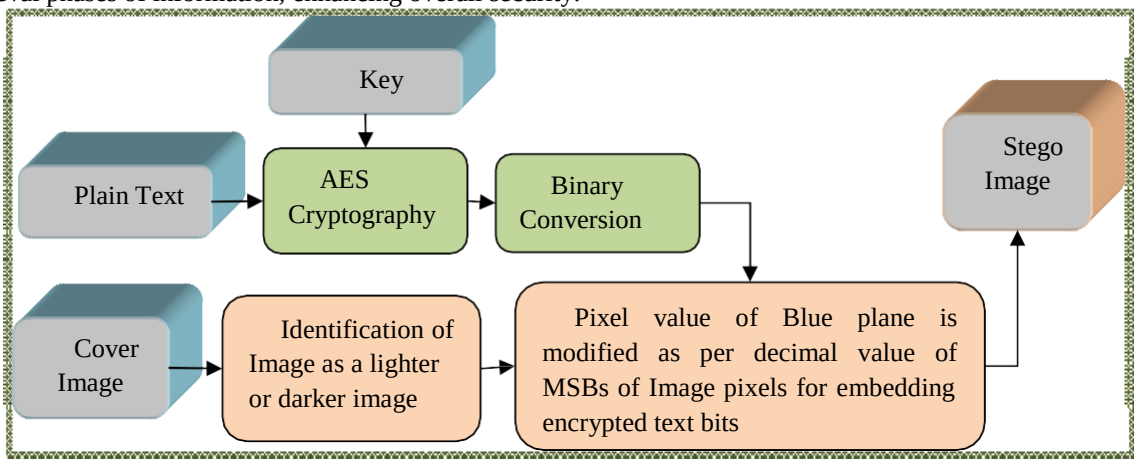


Figure 1.6 Enhancing LSB Image Steganography Through an Efficient Filtering-Based Method with the Integration of Status Bit and AES Cryptography

Figure 1.6 depicts the block diagram of the presented scheme. A new Steganography technique is introduced, utilizing a filtering-based algorithm that employs MSB bits for hiding extensive data in Bitmap images. The process involves embedding all message bits into the cover image to create a stego-image. Secret message

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extraction is achieved by reversing these processes.

1.2.5. Implementing a secure watermarking mechanism that relies on the integration of cryptography and bit pairs matching [5]

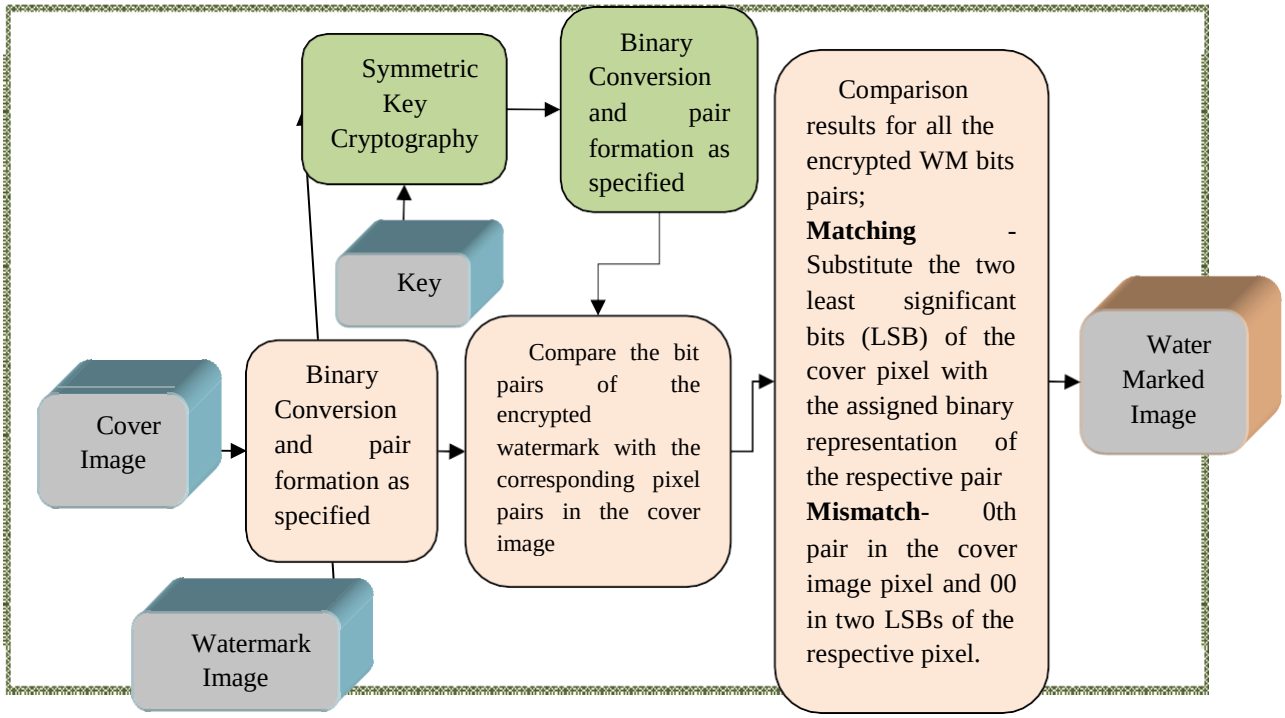


Figure 1.7 Secure watermarking mechanism that relies on the integration of cryptography and bit pairs matching

In the context of this research proposal [5], a method centered around bit pair matching is introduced. In this approach, pixel bits from both the cover image and the information to be embedded, specifically the watermark image, are paired and then subjected to a comparison process. Subsequently, the replacement of bit pairs occurs, contingent upon the identification of matching pairs. Figure 1.7 illustrates the block diagram, providing a detailed overview of the proposed scheme. Before insertion, the watermark image undergoes an additional layer of security through symmetric key encryption, resulting in the generation of encrypted data. To facilitate the decryption of data at the receiver's end, the quotient part of the pixel bits from the encrypted data undergoes multiplication by a 4-bit key, producing an intermediate result. This result is then added to the remainder bits of the encrypted data. If the resulting value is not an 8-bit number, necessary adjustments are made to ensure its conformity to an 8-bit representation. Finally, the number is reversed to obtain the decrypted data. The second layer of security is established through steganography based on bit pair matching. Initially, each pixel of the encrypted data is converted into its binary equivalent, followed by the pairing of the binary bits. Simultaneously, each pixel of the original image is also converted into its binary equivalent, resulting in the formation of four pairs. A matching algorithm is then applied to these pairs, enhancing the embedding process. The reverse process is executed at the receiver's end to meticulously extract the original watermark, completing a comprehensive and secure information embedding and extraction cycle.

1.2.6. A hybrid security approach integrating DCT and visual cryptography for safeguarding data communication networks [6]

This dual-layer mechanism introduces a fusion of Visual Cryptography (VC) and the frequency domain Discrete Cosine Transform (DCT) mechanism to enhance the security of confidential information during communication. Figure 1.8 presents a block diagram providing a comprehensive view of the proposed scheme. In the initial phase, sensitive data is encrypted by splitting it into shares through VC. Both shares are generated and merged to construct an encrypted message.

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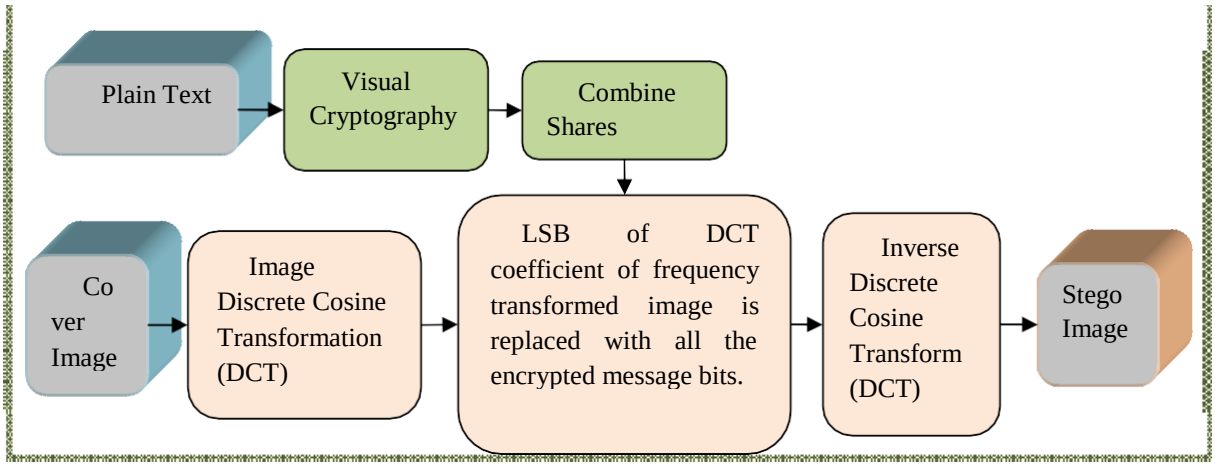


Figure 1.8 A hybrid security approach integrating DCT and visual cryptography for safeguarding data communication networks

On the recipient's end, the decryption process involves dividing the input into shares (Share1 and Share2), followed by the XOR operation on these shares to recover the original confidential data. In this context, the secondary security layer involves steganography. Here, the bits of the encrypted message are embedded into the Discrete Cosine Transformed (DCT) cover image, creating a stego image, which is subsequently transmitted over the network. The inverse process is executed at the receiving end to extract the message once again.

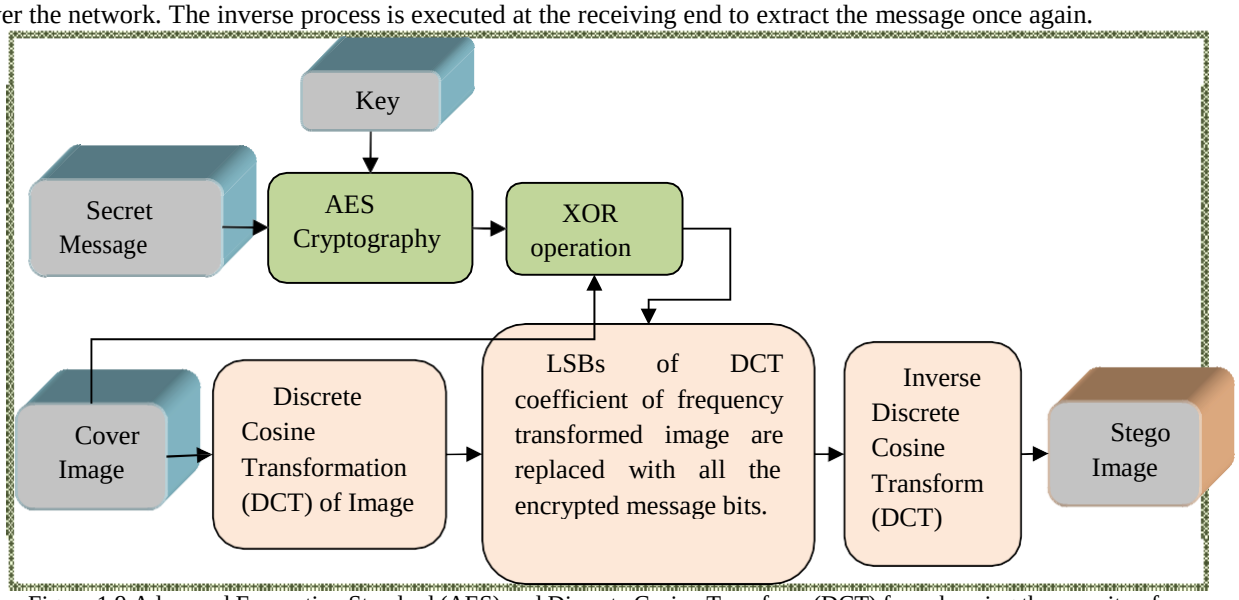


Figure 1.9 Advanced Encryption Standard (AES) and Discrete Cosine Transform (DCT) for enhancing the security of image steganography

1.2.7. Employing Advanced Encryption Standard (AES) and Discrete Cosine Transform (DCT) for enhancing the security of image steganography [12]

The provided proposal outlines a multi-layer security mechanism involving AES encryption followed by XOR operation on the encrypted information. This modified information is then embedded in a DCT-transformed cover image. Figure 1.9 illustrates the block diagram, providing insights into the described scheme. The initial layer of security involves encrypting the confidential message using the AES cryptography algorithm, resulting in ciphertext. The ciphertext undergoes XOR operation with the binary-converted pixel values of the cover image, leading to modified encrypted data. Simultaneously, the cover image undergoes frequency transformation via Discrete Cosine Transformation (DCT). The modified encrypted message is subsequently inserted into the least significant bit (LSB) position of the binary-converted DCT coefficients of the cover image. Finally, an Inverse DCT is performed to obtain the stego-image. The reverse process is executed at the receiver's end to extract the original data.

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1.2.8. A data hiding technique with a high embedding capacity based on EMSD and LSB substitution algorithms [9]

This work introduces a novel hybrid image steganography technique based on the LSB substitution and Enhanced Modified Signed Digit (EMSD) algorithm[9]. The proposed mechanism aims to significantly increase embedding capacity while maintaining acceptable visual quality. Figure 1.10 provides a block diagram, offering insights into the outlined scheme. As depicted in the block diagram, both the EMSD algorithm and LSB substitution are employed sequentially. Initially, the EMSD algorithm is applied to obtain the new pixel values, followed by the implementation of LSB substitution using these newly derived pixel values. The combined utilization of the EMSD and LSB substitution algorithms enhances the security of confidential data and yields an appropriate quality stego-image. On the receiver side, the data extraction process follows a similar approach using the Enhanced Modified Signed Digit (EMSD) algorithm.

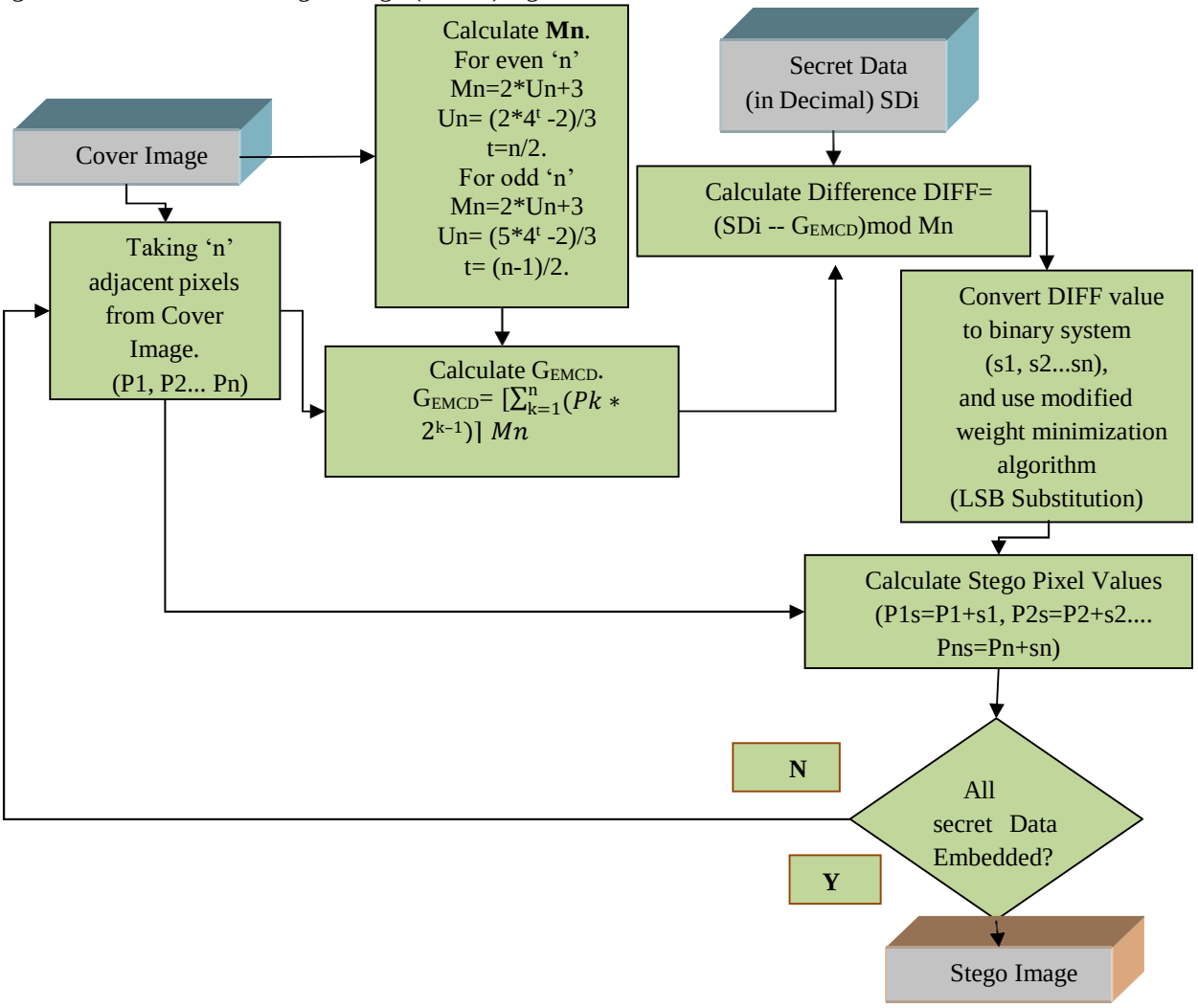


Figure 1.10. A data hiding technique with a high embedding capacity based on EMSD and LSB substitution algorithms

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1.2.9. A high-capacity steganography algorithm based on Pixel Value Differencing (PVD) with non-sequential embedding positions [8]

The Pixel Value Difference (PVD) scheme is employed in a twin-layer security mechanism with high-capacity steganography. Figure 1.11 provides a block diagram, offering insights into the described scheme. The embedding process utilizes both high and low-contrast pixels to store information, emphasizing Peak Signal-to-Noise Ratio (PSNR) and embedding capacity. Before embedding, the secret message undergoes encryption using a dynamic pairing function methodology. The second layer of security involves non-sequential embedding through a multi-bit PVD-based steganography algorithm. The embedding mechanism varies based on whether pixel pairs exhibit low or high contrast. Typically, more bits are embedded in high-contrast pairs to ensure imperceptibility, while embedding in low-contrast pairs is relatively inconspicuous. The consideration of low-contrast pairs increases the overall embedding capacity. At the receiver side, the reverse process is executed to extract the original data.

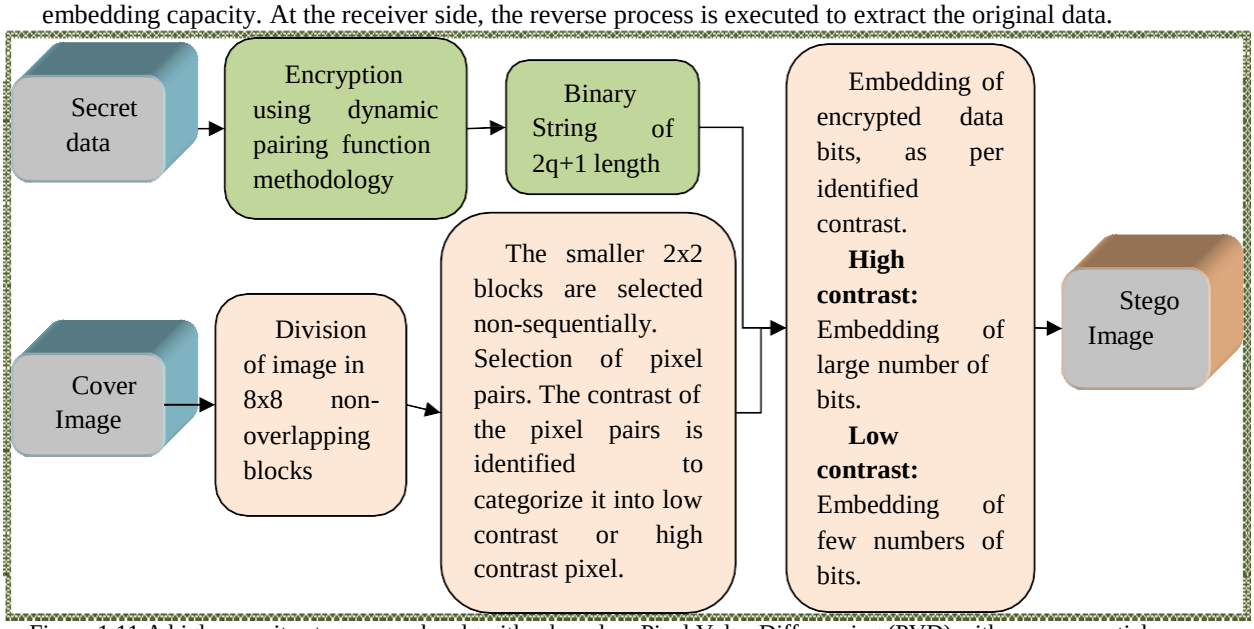


Figure 1.11 A high-capacity steganography algorithm based on Pixel Value Differencing (PVD) with non-sequential embedding positions

1.3. Comparison table (Dual-level security mechanisms)

In the exploration of a secure protection mechanism, numerous dual-level security mechanisms are proposed and implemented by researchers. The following table presents a brief study of the existing mechanism based on security parameters revealed below and the Table 1.1 presents a concise literature survey of dual-level security mechanisms. A blending of two methods endows with a better shield than the single layer of security, as demonstrated by various researchers.

Confidentiality (Con): It implies that there is meaningful communication of data between the designated sender and receiver, while for all others, the message remains unintelligible.
Integrity (Int): It signifies data reception at the receiver without any alteration, as the sender sent it.
Authenticity (Aut): It ensures the identity of the sender to avoid data communication with pretenders.
Reproducibility (Rep): It indicates complete retrieval of the confidential information by the recipient.
Imperceptibility (Imp): It implies the unintended recipient does not perceive data hidden in the carrier.
Computational Time (CT): It measures the execution time required by a particular algorithm or process.

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Proposed by	First Level of Security	Second Level of Security	Con	Int	Aut	Rep	Imp	CT
R.Nivedhitha, et al. [10], **2012**	DES	LSB Substitution	Y	N	N	N	Y	N
Ajay Nain et. al. [11], **2013**	RC4	Adaptive Pseudorandom	Y	N	N	N	N	Y
Neha Solanki et. al. [1], **2014**	RSA	DWT	Y	N	N	N	N	N
Md. Rashedul Islam, et al. [4], **2014**	AES	Status bit using LSB	Y	N	N	N	N	N
Sanjeev Narayan Bal [5], **2018**	Symmetric Key Cryptography	Matching of bit pairs	Y	N	N	N	N	N
Yamini Jain et. al. [6], **2018**	Visual Cryptography (VC)	DCT	Y	N	N	N	Y	N
Ashraful Tauhid et. al. [12], **2019**	AES	DCT	Y	N	N	Y	Y	N
Serdar Solak [9], **2020**	Enhanced Modified Signed Digit (EMSD)	LSB Substitution	Y	N	N	N	Y	N
Nabanita Mukherjee Ganguly et. al. [8], **2020**	Encryption using Dynamic Pairing Function	Pixel Value Difference (PVD) based steganography	Y	N	N	N	N	N

This section portrayed the existing dual-level security mechanisms. As seen from Table 1.1, presenting a concise literature survey of dual-level security mechanisms, the schemes are designed to provide comprehensive protection of the secret information (text/image), but still, all the objectives are not evaluated/ optimized by a single mechanism, also instances of online information exposure and data breaches are increasing. This gap between requirement and availability motivates the design of such a protection mechanism that can optimize all the objectives.

medical images [10]

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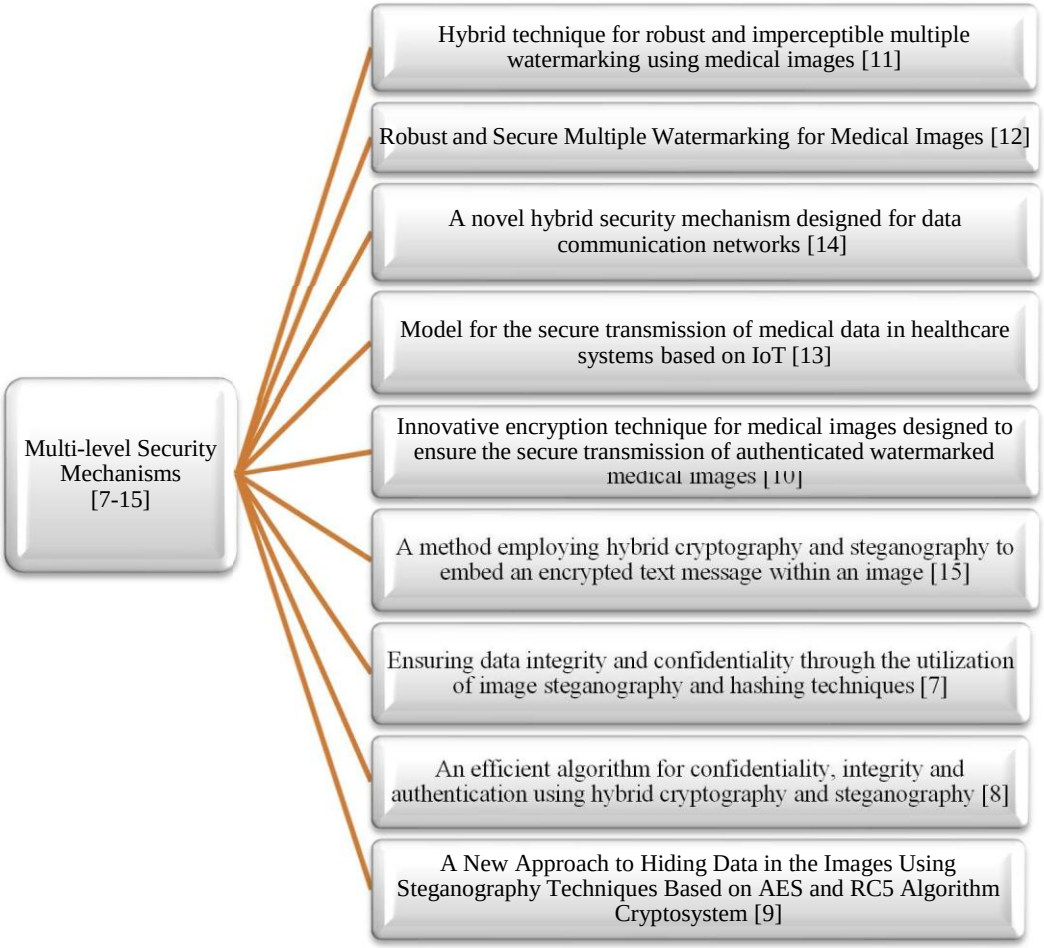


Figure 1.13: Multi-level security mechanisms

1.4 Multi-level Security Mechanisms

Figure 1.13 gives existing multilayer security mechanisms [19-24] proposed by numerous authors.

1.4.1 Hybrid technique for robust and imperceptible multiple watermarking using medical images [23]

This constitutes a multi-tiered security mechanism, comprising a cryptography layer and multiple layers of frequency domain steganography. Figure 1.14 provides a block diagram, offering insights into the described scheme. In this proposal, the utilization of Discrete Wavelet Transformation (DWT), Discrete Cosine Transform (DCT), and Singular Value Decomposition (SVD) is incorporated [23]. For identity authentication, the scheme embeds two watermarks into the cover image: a medical image as the image watermark and the Electronic Patient Record (EPR) of the patient as the text watermark. The final watermarked image is created by applying the inverse of SVD, DCT, and lastly DWT.

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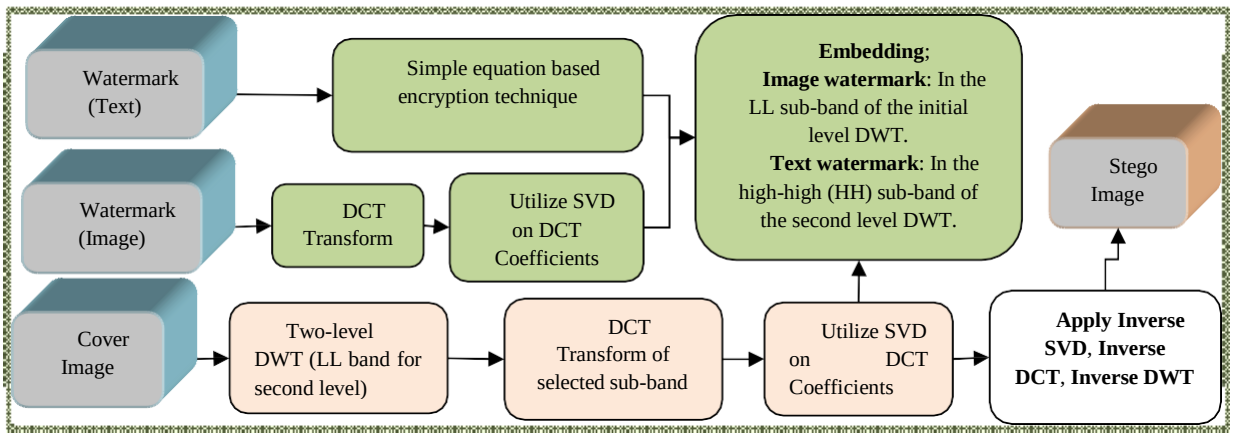


Figure 1.14: Hybrid technique for robust and imperceptible multiple watermarking using medical images

At receiver side, on similar lines all the processes are applied in reverse order for recover back the original medical image and EPR.

1.4.2 For medical images robust and secure multiple watermarking [24]

The provided approach suggests utilizing a combination of Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) to concurrently embed watermarks of medical images and Electronic Patient Records (EPR) [24]. Figure 1.15 illustrates the block diagram, offering a visual representation of the described scheme.

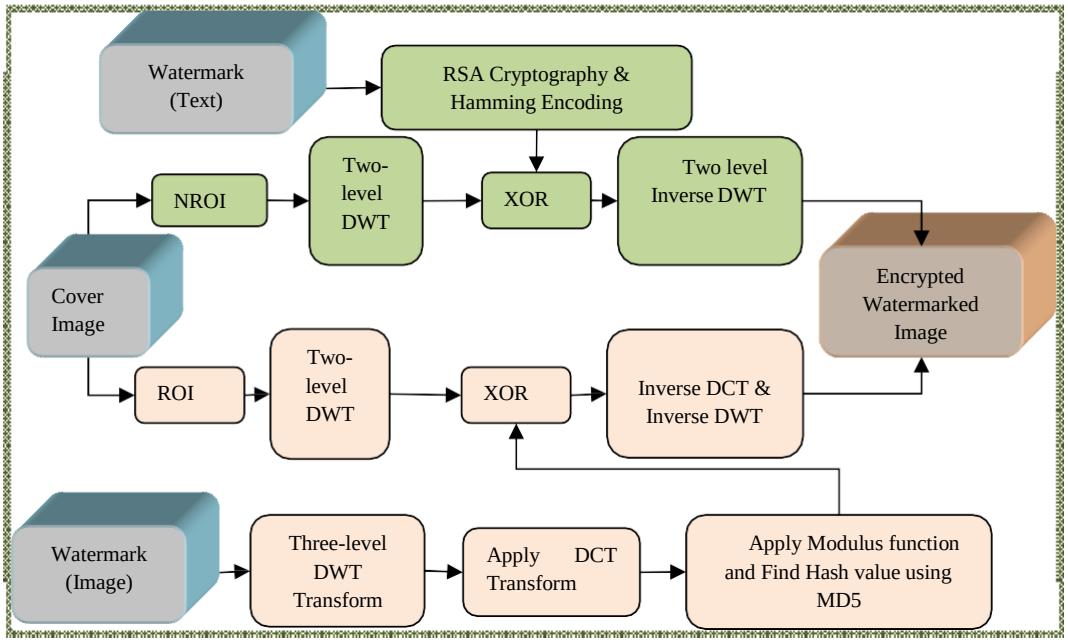


Figure 1.15: For medical images robust and secure multiple watermarking

Simultaneously inserting more than one watermark provides an additional layer of security and is crucial for verifying patient identity. To enhance security, encryption schemes such as RSA and the MD5 hash function are employed. Additionally, the Hamming error correction code technique is utilized to reduce the Bit Error Rate. The extraction of watermarks involves reversing all the processes. However, it's important to note that in this scheme, a noise texture resembling the resulting watermarked image is generated and applied exclusively to grayscale images.

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1.4.3 A novel hybrid security mechanism designed for data communication networks [26]

This proposal introduces a multi-layer security mechanism that employs visual cryptography (VC) followed by Status LSB substitution steganography. The confidential data undergoes initial compression through the Huffman lossless encoding scheme, followed by encryption using VC. Subsequently, this modified information is incorporated into the status bit-evaluated LSB substitution steganography mechanism. The cryptographic technique employed in this proposed mechanism is visual cryptography. Figure 1.16 provides a block diagram, offering insights into the described method. The extraction process is simply the reverse of the embedding process.

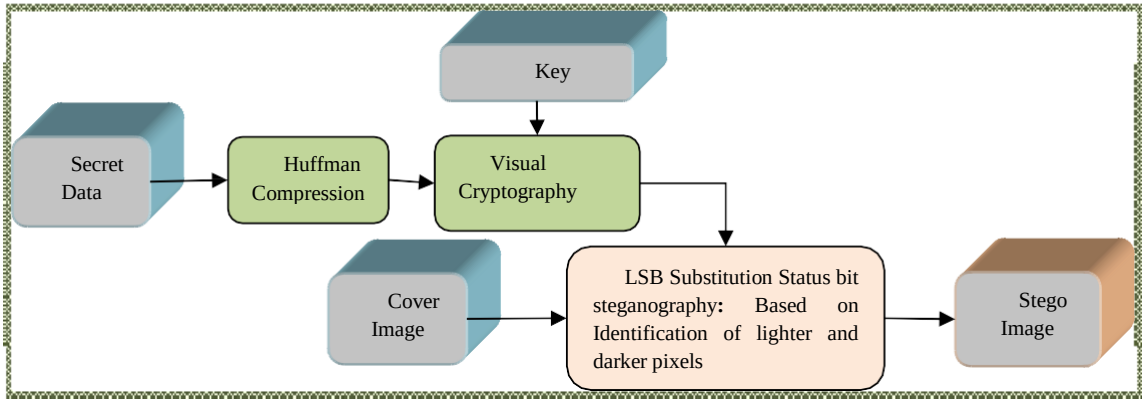


Figure 1.16: A novel hybrid security mechanism designed for data communication networks

1.4.4 Model for the secure transmission of medical data in healthcare systems based on IoT [25]

This constitutes a multi-level security mechanism incorporating a blend of dual encryption and steganography. Figure 1.17 provides a block diagram, offering insights into the described scheme. In this process, AES and RSA are employed in the initial phase to encrypt Electronic Patient Records (EPR). Subsequently, a two-level 2D-Discrete Wavelet Transform (DWT) steganography scheme is utilized to conceal the encrypted EPR within a medical image. For the encryption process, confidential data is divided into even and odd parts, each subjected to distinct cryptographic mechanisms—RSA and AES, respectively. The subsequent layer of security involves a steganography mechanism, employing Haar-Discrete Wavelet Transform (DWT). The extraction process mirrors the inverse of the embedding process.

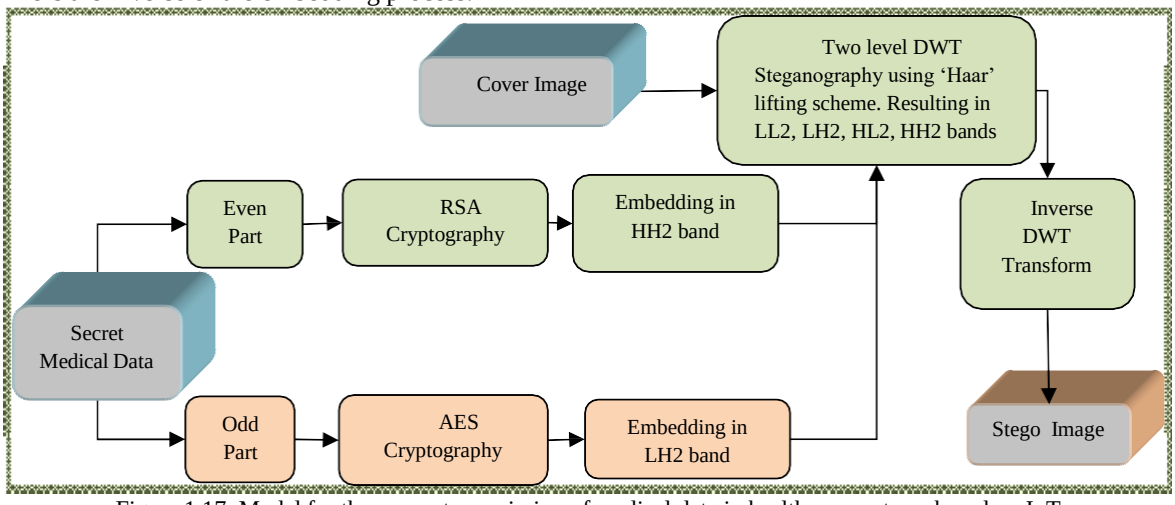


Figure 1.17: Model for the secure transmission of medical data in healthcare systems based on IoT

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1.4.5 Innovative encryption technique for medical images designed to ensure the secure transmission of authenticated watermarked medical images [22]

The proposed system encompasses the watermarking of medical images, incorporating Electronic Patient Records (EPR) hidden within a medical image, image encryption to generate a semantically meaningful encrypted image, and authentication for verifying the doctor's fingerprint. Figure 1.18 illustrates the block diagram, providing insights into the described scheme. This multilayer security mechanism comprises encryption and LWT steganography [22]. The subsequent layer of security involves an enhanced encryption mechanism termed Visual Meaningful Image Encryption. The final layer of security is implemented through authentication using the doctor's fingerprint image. The doctor's fingerprint image is converted to a binary format and then embedded in the least significant bit (LSB) of the wavelet coefficients of the transformed reference image. The extraction process mirrors the inverse of the embedding process.

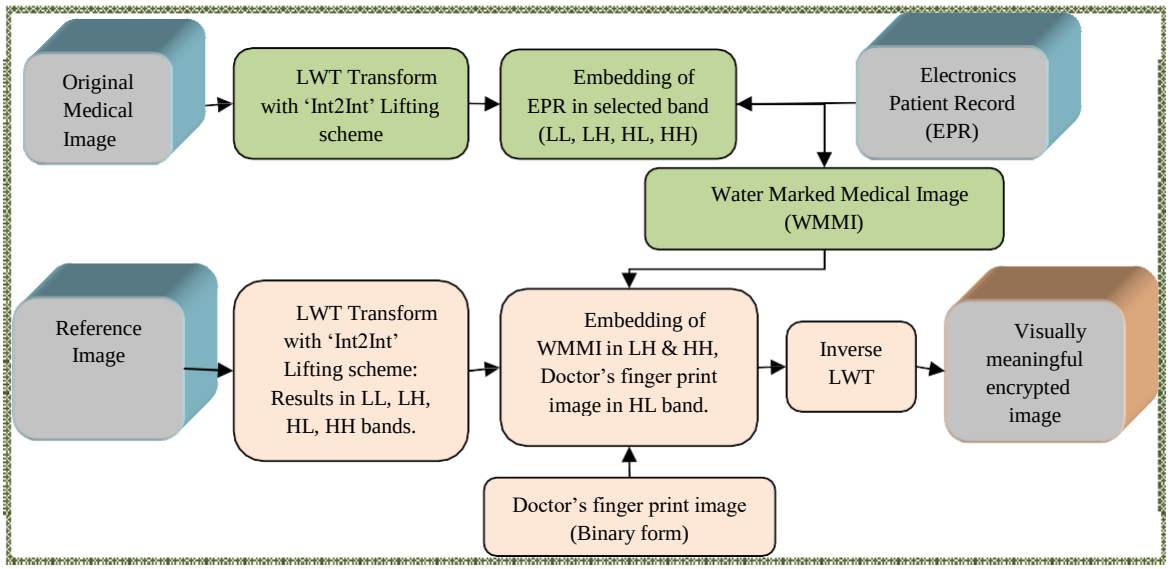


Figure 1.18 Innovative encryption technique for medical images designed to ensure the secure transmission of authenticated watermarked medical images

1.4.6 A method employing hybrid cryptography and steganography to embed an encrypted text message within an image [27]

The proposed model represents a multi-stage security mechanism with four integral stages: encryption of the original message utilizing the RSA algorithm, embedding the encrypted message into the cover image, extraction of the encrypted message from the stego-image, and ultimately, decryption of the ciphertext using the RSA algorithm key. Figure 1.19 provides a block diagram, offering insights into the outlined scheme.

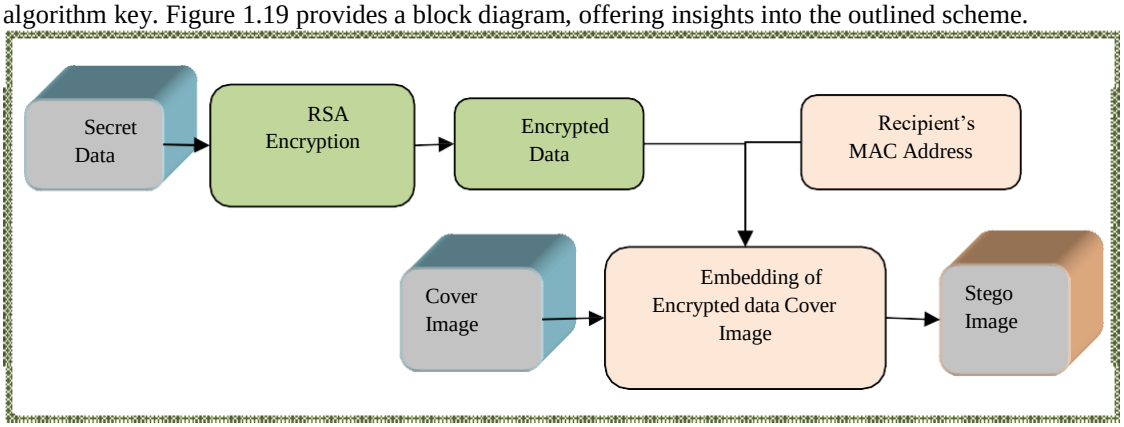


Figure 1.19: A method employing hybrid cryptography and steganography to embed an encrypted text message within an image

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As seen from Figure, this hybrid process consists of an encryption scheme employing an RSA algorithm followed by a steganography mechanism, which hides encrypted message and the recipient's MAC address for authentication purposes. So that, at the receiver end, the MAC-Address is checked before giving access to information to the recipient. If this address found correct, then further process for retrieval of an encrypted message is initiated, followed by decryption of ciphertext to get back the secret message.

1.4.7 Ensuring data integrity and confidentiality through the utilization of image steganography and hashing techniques [19]

The proposed scheme introduces a methodology that ensures both data confidentiality and integrity. The former is achieved by discreetly embedding data bits into the cover image, while the latter is attained using the SHA-256 function to generate a hash code of the encoding and decoding variables. Figure 1.20 illustrates the block diagram, providing insights into the described scheme. The defined approach integrates a novel steganography algorithm with the Hash function. The projected model encompasses four main stages: new image addressing, text size hashing, encoding, and decoding.

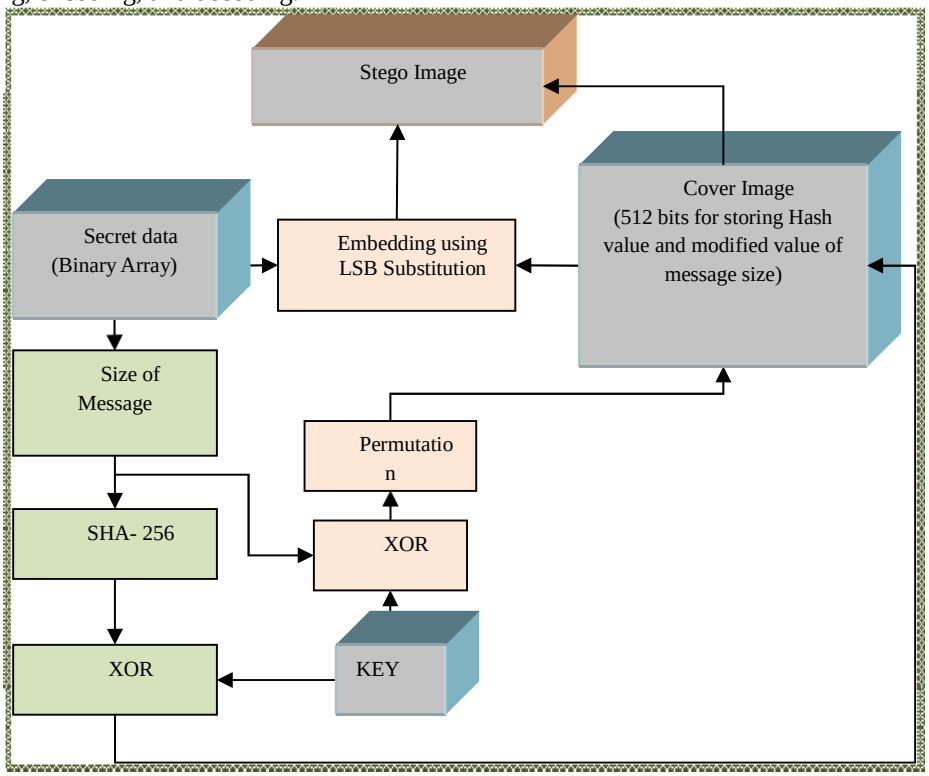


Figure 1.20: Ensuring data integrity and confidentiality through the utilization of image steganography and hashing techniques

The encoding process consists of two phases: first, calculating the address for embedding the text bits, and second, embedding the text bits in the encoded cover image to generate a stego-image. This involves distributing the hashed message size into the encoded cover image [19]. The decoding stage is also divided into two phases: the first involves retrieving the values of both halves stored in the last 512 pixels, retrieving the encoded message size. The receiver then calculates the hashed message size value and employs the XOR function with the shared key to ensure equality between the two values, thereby ensuring no data alteration occurred during transmission. The second process involves extracting the message bits from the stego-image and converting them back to the original text (plaintext).

1.4.8 An effective algorithm ensuring confidentiality, integrity, and authentication through the integration of hybrid cryptography and steganography [20]

In this system [20], multiple cryptography algorithms, including AES and RSA, have been implemented. As part of the security process, the symmetric key utilized for information encryption is additionally encrypted to

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enhance security. Additionally, a digital signature is generated by encrypting the hash value of confidential data. Finally, the encrypted secret data, encrypted symmetric key, and encrypted message digest are concatenated to form a comprehensive message. This entire package is ultimately secured using LSB steganography. Figure 1.21 presents the block diagram, offering insights into the described system. The specified system incorporates both asymmetric and symmetric encryption mechanisms. To retrieve information, all processes are employed in reverse order. On the receiving end, the digital signature is utilized to verify integrity.

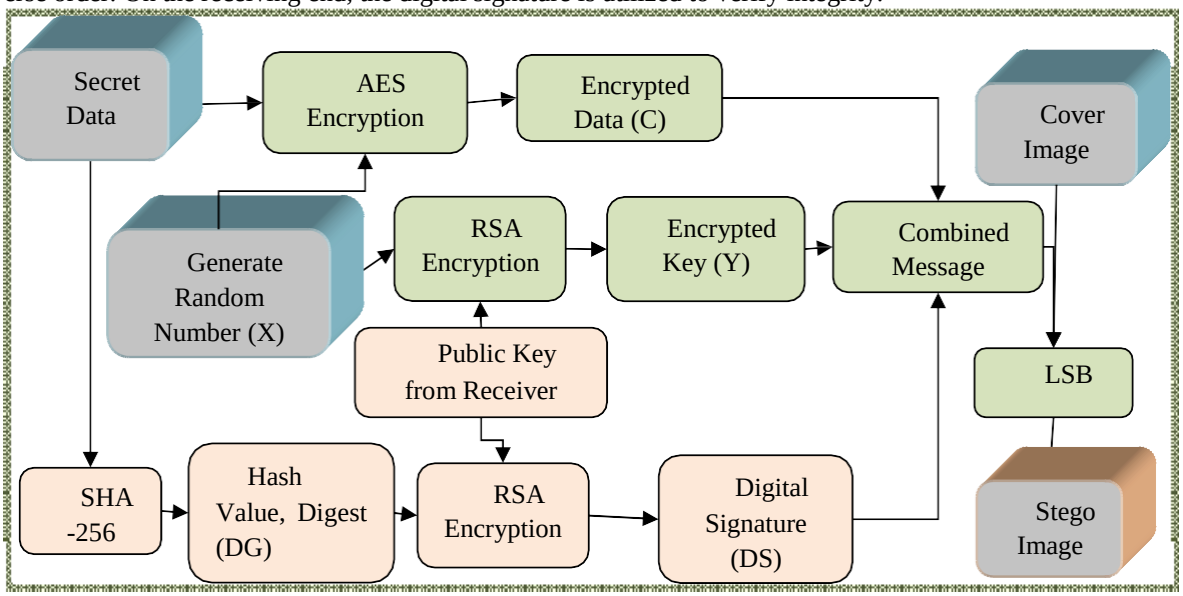


Figure 1.21: An effective algorithm ensuring confidentiality, integrity, and authentication through the integration of hybrid cryptography and steganography

1.4.9 A fresh approach to concealing data within images utilizing steganography techniques grounded in the AES and RC5 algorithm cryptosystem [21]

In the projected model [21], initially, the secret message undergoes an encryption process using two algorithms and results in a ciphertext. In the next security stage, this secured text is stored in an image to form a stego-object. This object is available to move through the internet for communication. On the receiver side, it is decrypted with the same two algorithms in a reverse manner. Finally, the recipient gets the original secret message.

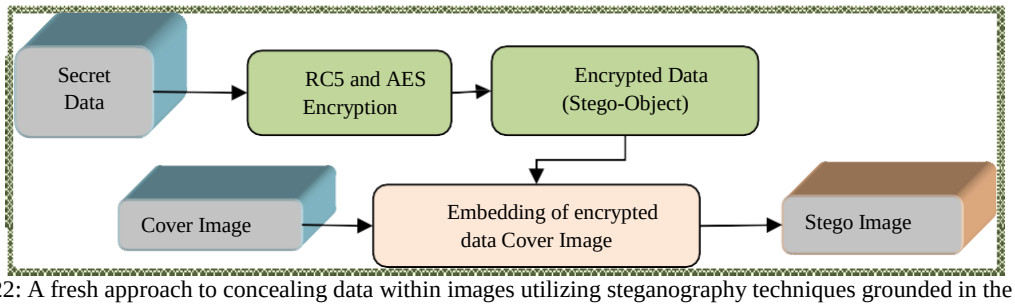


Figure 1.22: A fresh approach to concealing data within images utilizing steganography techniques grounded in the AES and RC5 algorithm cryptosystem

Figure 1.22 illustrates the block diagram, providing insights into the described scheme. In this scheme, a hybrid system is formed by combining two algorithms. The technologies enhanced with the proposed model include the Hybrid Algorithm System and Encryption and Decryption processes. Upon receiving the stego-object at the receiver end, the watermark is extracted, and subsequent decryption with AES and RC5 is performed to recover the original confidential message.

1.5 Comparison table (Multi-level security mechanisms)

In the exploration of a secure protection mechanism, numerous multi-level security mechanisms are proposed and implemented by researchers. The following table presents a brief study of the existing mechanism based on security parameters revealed above and the Table 1.2 presents a concise

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literature survey of multi-level security mechanisms. A blending of numerous methods endows with a better shield compared to the single layer of security, as demonstrated by various researchers.

Table 1.2. Literature survey of multi-level security mechanism

Proposed by	First Layer of Security	Second Layer of Security	Additional Layers of Security	Con	Int	Aut	Rep	Imp	CS
Amit Kumar singh et. al. [23], **2015**	Equation based Encryption	DWT Steganography	DCT & Singular Value Decomposition (SVD) Steganography	Y	N	N	N	Y	N
Abhilasha Sharma et. al. [24], **2017**	RSA, Hamming Code	DWT	DCT, MD-5 Hashing Function	Y	Y	Y	N	Y	N
Divya Chaudhary et. al. [26], **2016**	Huffman Compression	Visual Cryptography (VC)	LSB Substitution using status bit	Y	N	N	N	Y	N
Mohamed Elhoseny et. al. [25], **2018**	AES Encryption (Odd part)	RSA Encryption (Even part)	Two level 2-D DWT Steganography	Y	N	N	N	Y	N
S.Priya et. al. [22], **2019**	LWT with Int2Int lifting scheme	Visual meaningful image encryption	Fingerprint Biometric Authentication	Y	Y	Y	N	Y	N
Khider Nassif Jassim et. al. [27], **2019**	RSA	LSB Substitution	MAC Address Testing	N	N	Y	N	Y	N
Ahmed Hambouz et. al. [19], **2020**	New Image Addressing and Confusion	Text Size Hashing (SHA-256)	Encoding (Identification of locations followed by embedding)	Y	Y	N	N	N	Y
Chitra Biswas et. al. [20], **2019**	AES	LSB Substitution	RSA, Digital Signature	Y	Y	Y	N	Y	N
Md. Sagar Hossen et. al. [21], **2020**	RC5	RSA	DCT	Y	N	N	N	Y	N

This paper portrayed the existing multi-level security mechanisms. As seen from Tables 1.2, presenting a concise literature survey of multi-level security mechanisms, the techniques are implemented to give comprehensive safety of the confidential information (text/image), even then, most of the objectives are not evaluated/ optimized by alone mechanism; in addition, threats on data breaches is escalating. This difference between need and actuality motivates the researchers to design and develop a protection mechanism that can optimize all the objectives.

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1.6. Conclusion

To enhance security, researchers focused their attention on using multiple levels of security mechanisms. Various researchers have tried several amalgamations of steganography and cryptography techniques, but still, online data breaches are increasing, thus demanding further improvements in existing mechanisms. The data is first encrypted and embedded in a cover file in most multi-level approaches. Even if the intruder suspects the message's existence in the cover file, a cryptographic key is still needed to decrypt the secret message. An assortment of cryptography and steganography techniques can be combined based on the application to provide security to the data. Any security mechanism for ensuring security in communication should meet the essential network security requirements and stipulations of the applications for which employed, and majorly these are classified as; confidentiality, authenticity, integrity, reproducibility, imperceptibility, and optimized implementation time. This paper is committed to studying techniques that can accomplish most of these requisites. A wide range of existing multi-level algorithms are studied and implemented, and the following observations are taken:

- Most of the studied mechanisms' multi-layer or level constitutes cryptography, steganography, and some additional layer of security mechanisms.
- *Confidentiality* is the objective, which is evaluated/optimized by most methods.
- *Imperceptibility* parameter is evaluated/ optimized by some of the techniques.
- *Integrity* and *authenticity* are the parameters that have prime importance but are taken up by some proposals and must be looked upon by future researchers to be worked.
- *Computation time* is also a vital area to consider while designing or proposing new mechanisms.

This review of mechanisms endowed insight into existing literature for the researchers working in this area to better define the objectives for prospective work.

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INTERACTIVE DATA MANAGEMENT DEVICE FOR RENEWABLE ENERGY SITE MANAGEMENT

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Abstract

The power industry of renewable energy such as wind and solar power is receiving attention not only as an energy source to cope with depleted coal resources, but also as an environmental energy source from nuclear energy. The field of technology that is continuously required for the use of these renewable energy systems is the field of renewable energy maintenance. It is essential for industrial facility managers to ensure that the system is easily accessible, inexpensive, and easy to maintain. To solve this technical problem, this paper proposes the RMC(Remote Maintenance Controller) technology of the IoT LoRa(Long Range) technique. It was developed and designed a low-cost RMC that has the function of collecting field data from wind and solar power facilities based on IoT sensor input data and can control two-way data transmission. And It was implemented a hardware prototype for field data extraction and develop an IoT LoRa-based low-power communication module device for two-way communication management of the acquired data. The completed LoRa-based module integration device is tested/verified for use as a mid-to-long-distance transmission/reception function and as a general-purpose plant maintenance system. It was confirmed that the RMC technology system of the proposed IoT LoRa technique is an integrated management technology system for low-cost, high-performance power generation plants and can be used in mid- to long-distance two-way communication applications in wind and solar power generation systems.

Keywords

Renewable energy maintenance, RMC(Remote Maintenance Controller), IoT LoRa(Long Range), two-way communication management

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1. Introduction

Recently, the reduction of operation and maintenance costs in wind and solar power generation systems is considered a key part of renewable energy use management. Since the management and operation of such renewable energy power generation systems requires a lot of cost on the part of the power generation owner, improvement of management technology to reduce maintenance and operation costs and research on real-time repair processing technology in case of accidents are required[1].

In particular, operating conditions are often poor in wind turbine power generation an d remote solar power generation environments, and frequent regular inspection and ma intenance are difficult problems in remote environments[2]. For more economical main tenance of power generation output systems, the most important condition management at power generation sites involves real-time monitoring of power generation output an d a condition-based maintenance system[3][5]. Therefore, through this real-time status-based maintenance system, we would like to propose a hardware system of a bidirecti onal maintenance management system that is low cost and highly efficient[4][6]. For t he proposed low-cost, high-efficiency management system, bidirectional performance va riables for IoT output were derived by comparing the performance of the existing mai ntenance system. Based on the derived parameters, circuit design, two-way transmissio n performance evaluation, and field operation tests at remote power plants were condu cted.

2. System comparison / analysis

In the case of power generation systems such as wind turbines and long-distance solar energy, it is important to monitor operation and maintain maintenance in real time by transmitting power system data information to remote locations through wired and wireless communication lines that consist of grid protection devices and power systems[7]. In order to operate real-time management, such as transmitting on-site power generation output data to a remote location[8], a hardware system that analyzes and controls real-time management technology for maintenance was implemented in this study. Since the real-time monitoring system is essential for wind power generation facilities, it is a facility that must be equipped in all power generation systems, and its characteristics such as power generation output for the development of low-cost maintenance technology are analyzed in the system design.

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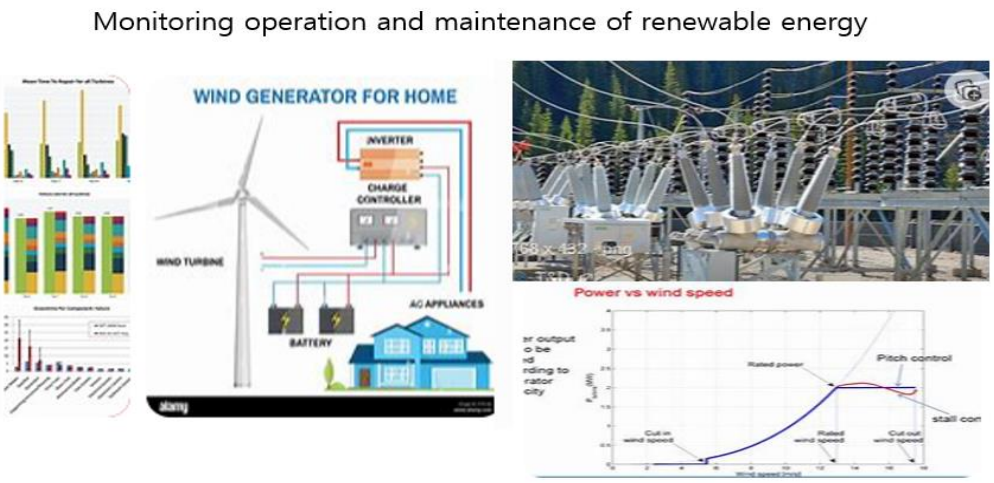


Fig.1 Operation and remote maintenance of renewable energy production power

The condition-based maintenance of the proposed system eliminates unnecessary regular maintenance tasks, enabling high reliability and low maintenance costs.

In the case of wind power generation in renewable energy generation, it is possible to reduce the operating and maintenance costs of wind power generation through continuous monitoring of turbine conditions. Through the analysis of the state of the management and control system and the analysis of the status of maintenance variables, it can be applied to the maintenance system with improved stability.

Various power generation system models and modules have different types of failure modes. The proposed system reveals the top failure modes that will be subject to health status monitoring and condition-based maintenance. Monitoring and management of comparative analysis of power generation models is necessary. Environmental defect monitoring and diagnosis of specific components are performed based on vibration and temperature data. In the proposed system, supervisory control IOT data collection (SCADA) confirmation and performance monitoring monitors the basic process and analyzes the abnormality and error detection functions of the entire turbine.

By comparing characteristics through various parameters, functional characteristics are selected that can increase efficiency and enable low-cost design.

- The RMC equipment-type remote management system proposed in this study has real-time situation detection of electrical abnormalities such as power when power is generated and various sensor detection type data management characteristics.
- When an accident occurring in the field system is detected, this system classifies the alarm system into various stages, performs a remote transmission function of signal values to the user

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management system for each alarm, and performs real-time accident processing.
- If the user's handling of the incident at the power generation site is uncertain even after the final decision has been made, it is an efficient maintenance system that auto matically blocks related maintenance technology.

The differences between the proposed method and existing technologies are as follows.

- Differentiation analysis of existing market penetration methods and maintenance technologies
- The existing post-response maintenance method is common in solar power plant management.
- Compared to remote management systems among existing maintenance systems, the newly developed system can detect power/electrical abnormalities when applying a remote management system using RMC equipment.
- The user alarm system is classified into 4 stages and stages 1 to 3 are delivered to the user's decision-making for each alarm.
- This system introduces an efficient maintenance system that automatically blocks broken related devices and responds to related maintenance technology if the user's transmission is not made even after the final decision point.

The experimental technical comparisons of the proposed technical system and the existing system is shown in the table 1 below.

Table 1. Comparisons of the proposed technical system and the existing system.

Category Type	General System	Proposed System
Local Device Instrument	Desktop PC + Monitor Data Converter Windows OS Software	Embedded Device based on Linux OS
Data Communication Type	Local Database Same with Server Transmission Data High data loss risk	Cache local data. Lightweight design of server transmission data. Low risk of data loss.
External Communication Type	Local monitoring Web monitoring (Ethernet)	Primary communication channel (Ethernet) Auxiliary communication channel (LoRa)
Internal Communication Type	RS-485, RS-422	Modbus_RTU Modbus_TCP RF (400MHz band) RS-485/ 422

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3. Design the Overall System for On-site two-way data communication System

We proposed a condition-based maintenance system as shown in Fig.2 below, which aims to reduce stable operation and maintenance costs at power generation sites and analyze and manage the status of the system through continuous precise monitoring during the power generation operation of various renewable energy power generation systems.

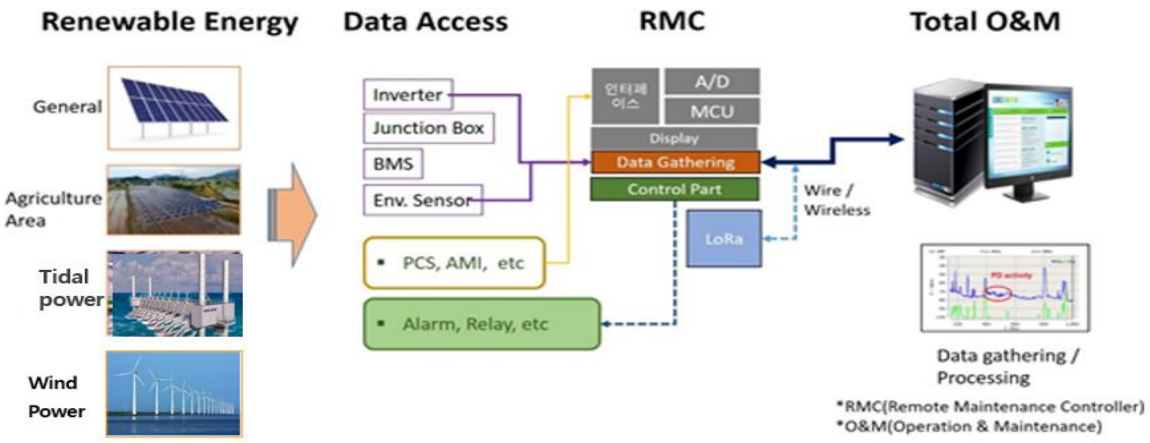


Fig.2 Renewable Energy Power Generation System Operation System

In the overall system configuration of the proposed two-way maintenance management system, when power generation energy such as general solar power generation, wind power generation, and tidal power generation is produced, information on the power generation data is output to an on-site IOT data sensor and data is sent to a remote location.
Here, the detailed hardware interface of RMC is structured as shown in Fig.3 below.

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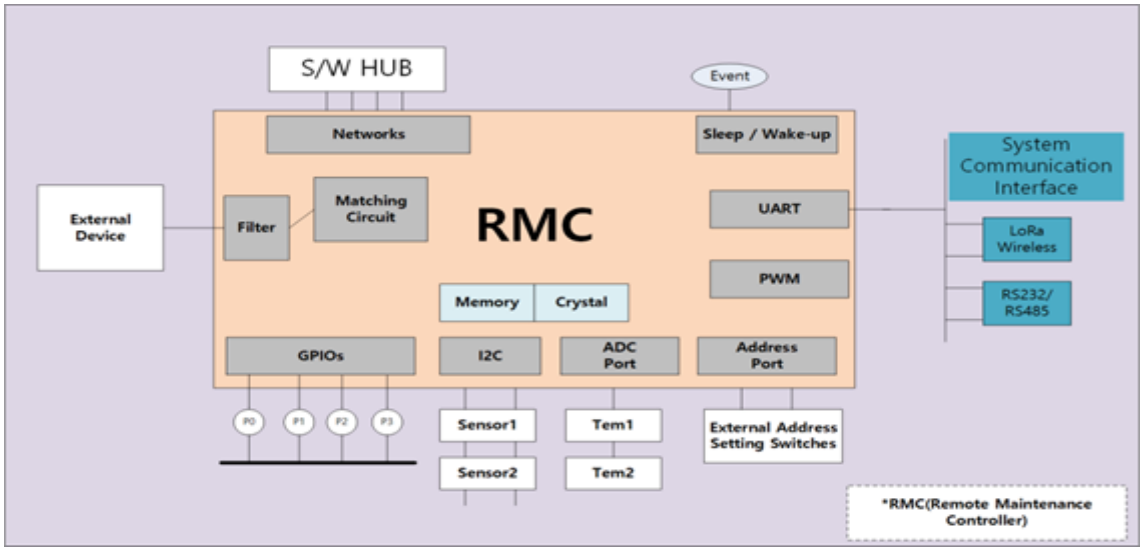


Fig.3 RMC Interactive data management configuration diagram

The data flow of the maintenance system in the renewable energy field system plant is table 2.

Table 2. Data flow of the maintenance system

IOT Sensor Parameter	Power Target Performance
Communication reliability	97% or more, Two-way Transfer
Power Consumption	Less than 20Wh
RMC connection quantity	More than 50 nodes
User concurrent access	More than 50 nodes
Number of supported equipment types	More than 10 types

4. RMC Hardware Device for On-site various communication

An optimal hardware system was implemented for a various transmission system for production power and real-time maintenance of a renewable energy power generation system.

The RMC hardware design details performed for field IOT data collection and control are as follows.

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- Perform Compact Type embedded H/W design and development for each field environment
- RMC hardware configuration in the form of an embedded system
  - · SD card interface design for storing IOT sensor data
  - · DDC design for stable power supply to power system
  - · Touch screen interface design for power site manager interface
  - · Network interface design for LoRa communication facilities
  - · Design of I/O and RS232,485 communication at power generation site

Hardware Configuration of RMC is structured as shown in Fig.4 below.

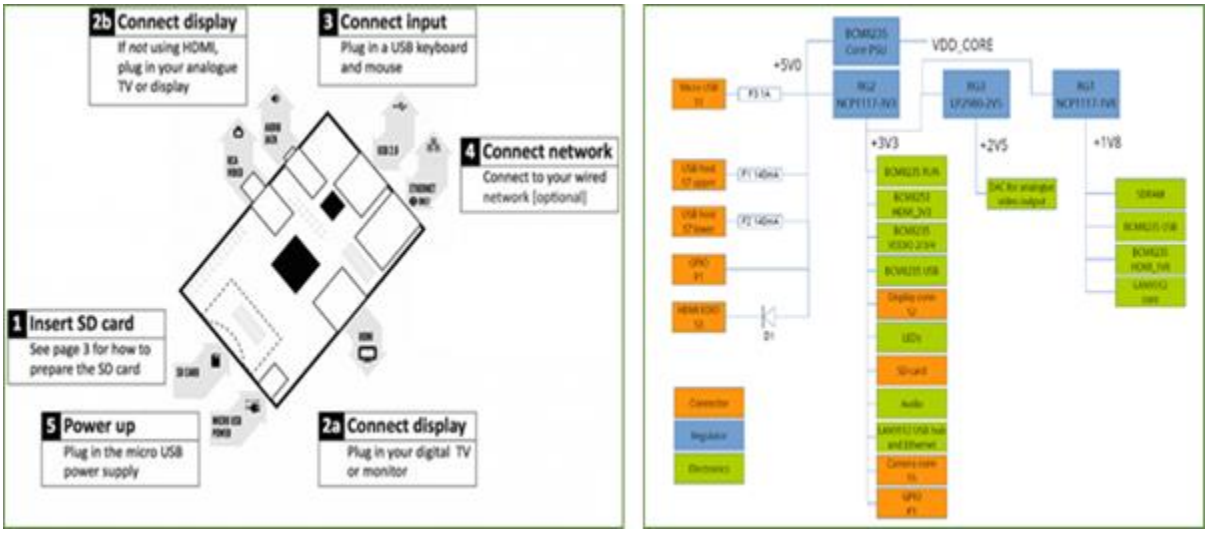


Fig.4 Hardware Configuration of RMC System

The detailed design details of the RMC power supply circuit design are summarized. To comply with these design specifications, an isolated DC/DC converter is designed in Fig.5 below.

The detailed hardware of the RMC power supply circuit design was designed.
The important role of the power supply unit is to protect the internal circuit from external noise, supply stable power to communication units such as RS-485, and protect the internal circuit in the event of an electrical accident. In order to comply with these design specifications, an

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isolated DC/DC converter is designed and applied to the device to perform real-time maintenance work on signals generated at the site of a renewable energy power generation device.

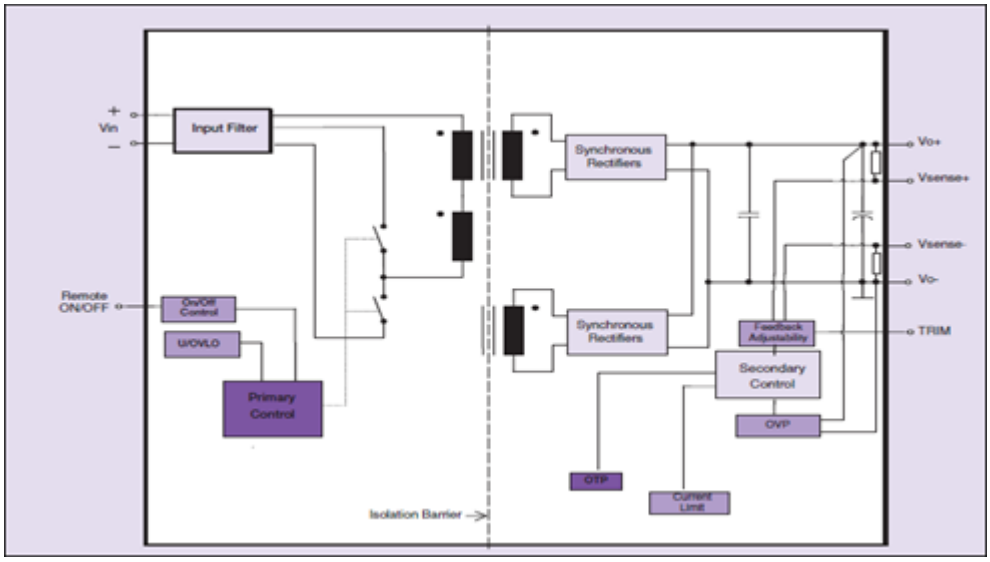


Fig.5 Block Diagram of Isolated DC/DC Power Converter

5. Design for the RMC Simulating systems

The following describes the structure and functions for the RMC Simulating systems in Fig. 6 below.

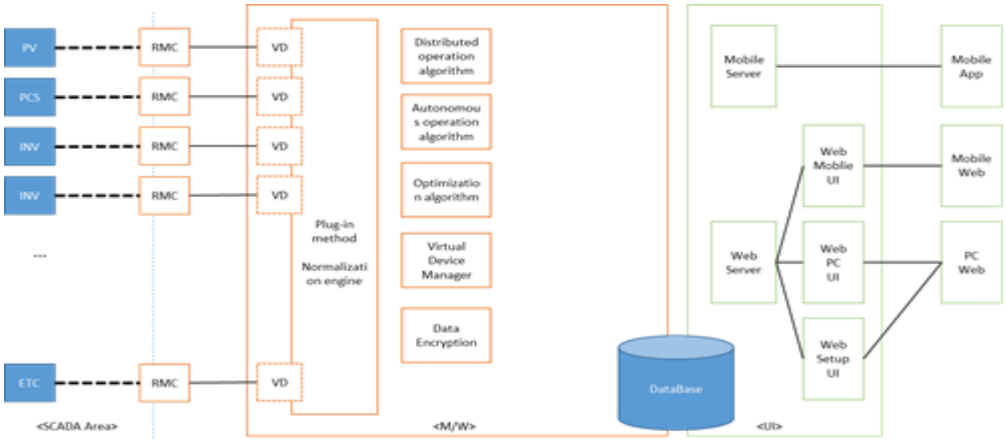


Fig.6 RMC S/W Design Concept

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The most important Structure of RMC Simulating systems are the following three elements.

1) Real-time data collection and transmission module at the renewable systems
   - Collect power equipment data from various suppliers
   - Design of server communication function of communication device
   - Configure normalization of collected/saved data
   - Design and implementation of environmental data
2) Development of wind and solar control interface technology
   - Apply real-time control command protocol to block functions when abnormal situations occur
   - Configuration of command delivery and execution system that can handle operation response time
3) Development of electrical data collection and various transmission module
   - Monitoring the power status of grid power inlets
   - Monitoring according to the level of the protection device

6. Performance Test and Verification

The real-time transmission of power generated by remote wind and solar power generation sy stems and the testing and validation work carried out to verify the characteristics of the mana geable hardware are shown in Fig.7 below.

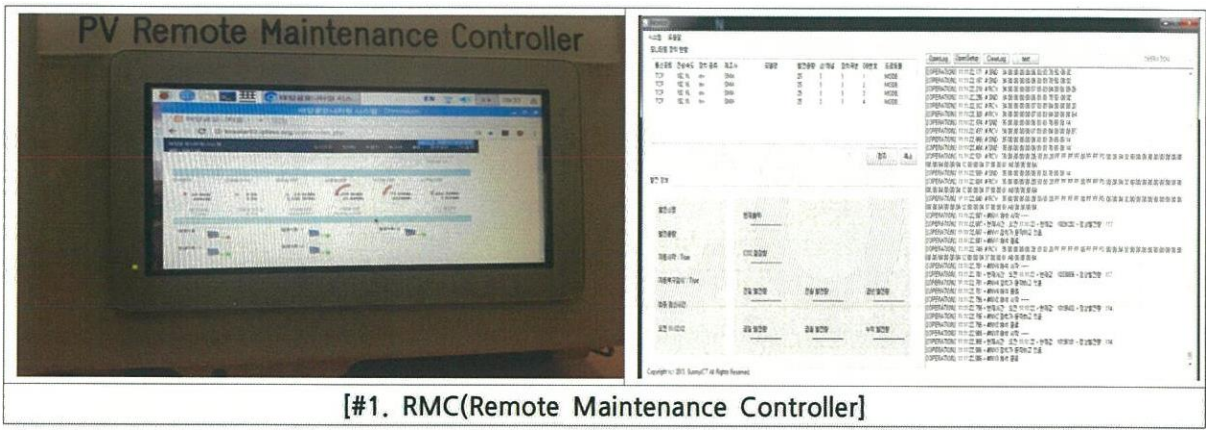


Fig.7 RMC Device Test for Characterization

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After connecting the RMC installed in the field and the inverter, the average power consumption measured 30 times for 1 minute was 16.28 Wh.
In this experiment, the proposed system was tested on a control command protocol that can block functions when an abnormal situation signal occurs in a remote renewable energy power generation device. When tested under RMC 50 node conditions to ensure that the operation response time generated was minimized, it was confirmed that the executed command transmission and experimental results resulted in an overall accurate effect of more than 97% in field installation devices.

7. Conclusion

RMC system hardware was implemented to conduct a characteristic test, and the performance of the output field data was confirmed through the experimental results. In addition, a low-power, stable-performance device for maintenance has been implemented.
Through identifying the characteristics of the server system, the maintenance of new and renewable energy power plants can be further improved.
The proposed renewable energy RMC controller is an O&M system that can be applied to small-scale power plants, and is technically applicable to various power plant markets. Our proposed system technology can expand services for small-scale power generation companies, and it brings the economic savings by using IoT sensing networks. We can apply to various maintenance systems such as renewable energy systems through our RMC control systems.

Acknowledgement

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Analytical Expressions for Bacterial Communication under Biological Cylindrical & Spherical Deployments

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Abstract: Molecular Communication via Diffusion (MCvD), which is a type of Molecular Communication (MC), is being utilized to study the propagation of bacteria inside the human body. MCvD and thus the propagation model depend on the type of deployment used. There are three types of deployments, including rectangular, cylindrical, and spherical. However, in this research, cylindrical and spherical deployments are used. Furthermore, analytical expressions for bacterial concentration $A(r, t)$ are proposed under both deployments, namely, spherical and cylindrical. Additionally, the analytical expression for rise time $T_r(r, t)$ is also presented for the deployments under consideration. It is noteworthy to mention that the input concentration of molecules transmitted from the transmitter bio-nanomachines (T-BNM), $f(r,t)$, is the same for both cases. For numerical quantification of the proposed expressions, the parameters used are the rate of molecule transmission (N), distance from the transmitter (r), and time it takes for the molecules to propagate (t). Finally, all the results are simulated, and it is found that the simulated results match the theoretical observations

Keyword

Diffusive Molecular Communication , Rise Time , Bacterial propagation , Concentration of Molecules , Spherical Deployment , Cylindrical Deployment.

1. Introduction

1.1 Background

Molecular Communication through Diffusion is a groundbreaking paradigm, employing microscopic molecules to seamlessly transmit data from transmitter bio-nanomachines to receiver bio-nanomachines. When compared with traditional communication systems, MCvD leverages messenger molecules (MMs) as information carriers, selected for their remarkable combination of high biocompatibility and energy efficiency [1]. These molecular messengers navigate through a fluidic environment, demonstrating Brownian motion—an aspect which exhibits varying characteristics compared to the physical layers of conventional communication systems. MCvD also explains the phenomena of how bacteria travel within the human body. These bacteria harness the abilities of diffusive molecular communication to exchange information. This sophisticated communication link enables bacteria to execute

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complex tasks, from the production of light to the attack on host cells [1]. In this vast domain of molecular interactions, the potential for innovation and discovery unfolds, marking a transformative remark on our understanding of communication within biological systems

1.2 Literature Review

The behavior of bacterial propagation highly depends on the configuration of the system in which the communication process takes place. Mainly, three types of configurations are considered: rectangular, cylindrical, and spherical. In the case of rectangular channels, the frequencies at which communication takes place are limited due to the increase in attenuation as frequency increases [2]. On the contrary, bounded cylindrical deployment is considered a more suitable model for microfluidic channels [3]. In [4], the author proposes modeling blood vessels as cylinders, widely accepted for designing Diffusive Molecular Communication (DMC) systems within blood vessels for healthcare applications. Bounded spherical deployment is suggested for biological structures like the stomach, lungs, and kidneys, aiding in predicting drug concentration profiles for targeted drug delivery [5].

In [6], the basics of molecular communication within nano-networks have been explored, including discussions on channel description, channel capacity, protocol design, and the setup for experimental validation. Authors in [7] describe the opportunities and issues associated with molecular communication, while [8] examine various challenges that set molecular communication apart from traditional wireless communication. The analysis encompasses concerns such as inter-symbol interference and channel coding.

From [9], we understand that MC's communication range is constrained by channel attenuation from molecular diffusion and decay, causing significant channel distortion due to the stochastic nature of Brownian motion and unpredictable chemical reactions. This distortion results in limitations on the minimum time interval between message transmissions, leading to pronounced inter-symbol interference (ISI)

Mitigating intersymbol interference in diffusive molecular communication using enzymes is presented in [10]. Enzymes form reaction intermediates with information molecules, degrading them to prevent interference. The study includes a lower bound expression for the expected number of molecules at the receiver and proposes a binary receiver detection scheme. Insights are provided on selecting a suitable bit interval, and the expected bit error probability is derived. Simulation results confirm the accuracy of the bit error probability expression and highlight improved communication performance with active enzymes.

The author in [11] introduces a novel approach for medium-range communications (nm-μm) in Nanonetworks, focusing on the interconnection of nanomachines. While existing techniques use molecular motors, calcium signaling (for short distances), and pheromones (for long distances), the proposed method employs flagellated bacteria. The technique involves the transport of DNA-encoded information between emitters and receivers via a bacterium. The paper provides a physical channel characterization and presents a simulator that simulates the transmission of a DNA packet between two nanomachines based on the characterized channel.

In [14], the author presents a new way of looking at how cells communicate, combining concepts from both biology and communication engineering. They suggest a hierarchy of communication in cells, inspired by how chemicals transmit signals within them. This hierarchy consists of five levels, covering everything from how signals spread to practical applications. The author illustrates this hierarchy with examples like quorum sensing and

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neuronal signaling. It also points out areas where more research is needed at each level, stressing the importance of combining different levels of understanding. Overall, the paper aims to give communication engineers a structured approach to understanding biological systems and to help biologists see how engineering ideas can influence cell signaling. This, in turn, could lead to new solutions that bridge the gap between these two fields

In [15], the author investigates how diseases spread, especially through the air by tiny particles like viruses and bacteria. The research concentrates on how droplets, such as those from coughs or sneezes, can carry these germs. To better understand this, the molecular communication approach is used, which helps create a model showing how diseases move between people. This model begins with someone releasing droplets containing germs and ends with another person getting infected

In [18], the author has proposed various closed-form expressions for bacterial concentration, taking into account the spread of the SARS-CoV-2 virus over the respiratory tract. The effect of SARS-CoV-2 on humans and the economy has been precisely studied

In [19], the author discusses Diffusive Molecular Communications (DMC), which has attracted attention for its simplicity and energy efficiency in communication from very small to larger scales. However, DMC faces a challenge called inter-symbol interference (ISI), making it difficult to achieve reliable and fast data communication. The paper investigates recent studies on improving DMC performance, highlighting important areas of research. It discusses signal design and addresses limitations in that process. Additionally, the paper examines the basic limits of information in DMC and discusses various methods for setting up the sending and receiving components.

Experimental research on Synthetic Molecular Communication (SMC), focusing on long-range systems that can communicate over more than a few millimeters, is shown in [20]. Furthermore, the author highlights the importance of this research for evolving SMC into a mature communication method that can support groundbreaking applications. The existing literature on this topic is limited, so the paper explores long-range SMC in both liquid and air. These systems use molecules to encode and transmit information, but they differ in designs and intended uses.

The effect of COVID-19 has also been extensively studied in [23]. The article addresses the impact of respiratory diseases, including COVID-19, and emphasizes the importance of early diagnosis for timely treatment. It introduces a hybrid framework, HQF-CC, for respiratory disease detection using Chest X-rays. The author highlights the rapid global spread of the virus, leading to its declaration as a pandemic by the World Health Organization in March 2020

1.3 Research gap and motivation

Among various published work on MCvD, we observed that there is a lack of closed form expressions required to represent the variation in bacterial concentration as a function of time and distance along with the effect of propagation delay for different types of deployments. In order to provide a thorough understanding of the mathematics involved in deriving these closed form expressions with minimum assumptions we have presented this work, which involves application of MCvD for representing bacterial concentration along the diffusion channel.

1.4 Challenges

One prominent issue is the considerable propagation delay inherent in MC, this delay increases rapidly as communication distances increase. Such delays pose challenges for tasks like

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information re-transmission and system synchronization. Additionally, understanding the concentration of bacteria under spherical and cylindrical deployments is required to clarify the propagation process further. In addition to communication delay, the communication range of MC is strictly limited by channel attenuation. Meanwhile, the stochastic nature of Brownian motion and the unpredictable chemical reaction produce significant channel distortion, which limits the minimum time interval between two message transmissions and creates severe inter-symbol interference (ISI).

1.5 Major Contributions

The author's contributions to this manuscript are summarized as follows:

- Consideration of Cylindrical and Spherical Deployments for deriving the expressions for bacterial concentration along the diffusion channel.
- Taking into account the effect of propagation delay by modeling rise time under both the deployments
- Presents the variation of bacterial concentration and rise time as a function of various parameters like release rate of bacteria molecules (N), length of diffusion channel (ρ/r) , time of propogation for the molecules (t)

1.6 Paper Organization

The rest of the paper is organized as follows. In sec II we present the system model for cylindrical and spherical deployments and present various mathematical expressions required for analyzing bacterial concentration and propagation delay. In sec III Mathematical expressions for bacterial concentration for both the deployments and propagation delay has been shown for different deployments. Sec IV contains the numerical analysis of the proposed closed form expressions to verify them with theoretical findings. Sec V is the conclusion of this work comprising the future scope in it and sec VI provides all the references required during our research.

2. System Model

We consider two configurations of the communication system from transmitter to receiver bio-nanomachines including the diffusion channel. The bacteria molecules are considered to be stored in Transmitter bio-nanomachines while there are certain types of molecules that these bacteria use to communicate and exchange information among them. At the receiver end the bacteria propagates via a diffusion channel and while propagating it makes use of molecules already present inside the body(fluidic medium). The transmitter releases the bacteria in such a way that their concentration varies along the distance r and with time t. When this bacterium gets attached with the molecule, the molecules help the bacteria to propagate to the receiver end via diffusion through the medium and thus the process of communication is achieved.

Shown below is the presented system model for Cylindrical and Spherical Deployments. By the term deployment we mean that the whole communication setup including the Transmitter Bio-nanomachines, the diffusion channel and the Receiver Bio-nanomachines are placed under a coordinate system that can be either cylindrical or spherical in our case and every point from the transmitter to receiver is described in terms of the respective coordinates of that system.

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For Cylindrical we have (r, θ, ϕ) and for Spherical we have (ρ, θ, ϕ). When the bacteria propagates along the diffusion channel length, then only r or ρ varies from the origin.

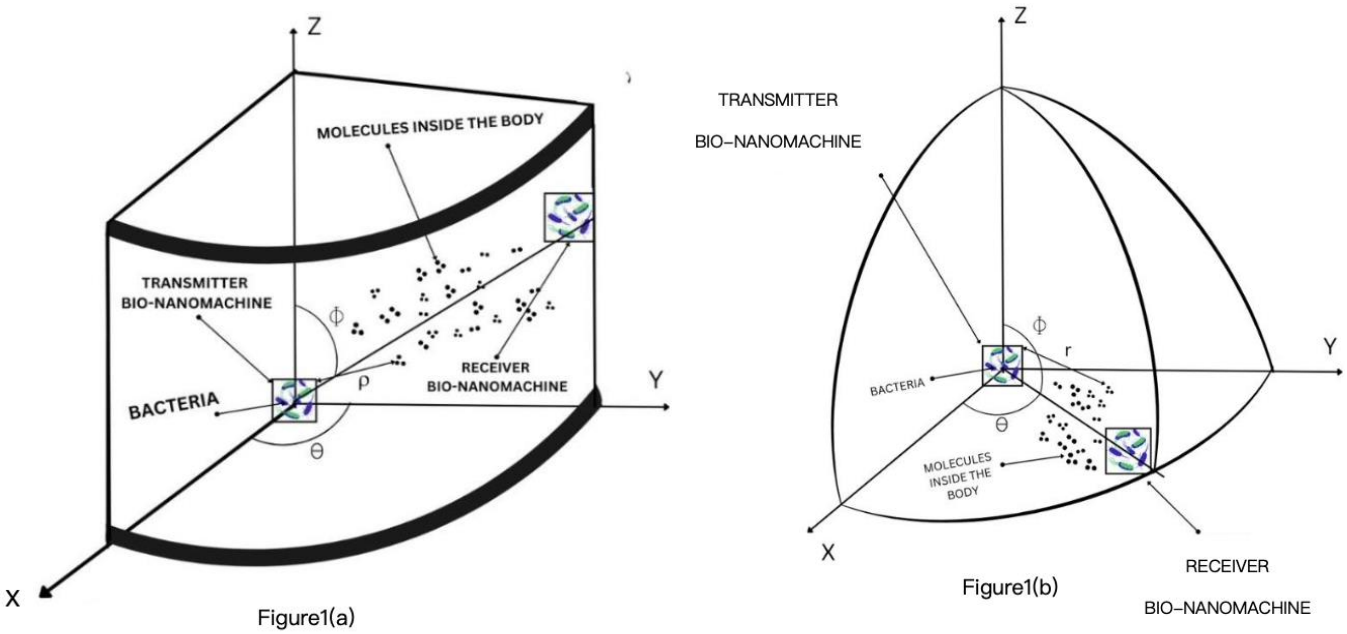


Figure 1 represents System model for Bacterial Propagation under (a) Spherical and (b) Cylindrical Deployments

For better visualization, we considered the transmitter to be placed at the origin and the receiver at a particular distance from it. The molecules are present throughout the deployment, but for a clear presentation, we have shown them only between the Transmitter and Receiver bio-nanomachines. The delay in the communication process occurs when the bacteria molecules diffuse through the channel. To evaluate this delay, we also proposed the expression for rise time in the subsequent sections.

Further, to explain some terminologies in the mathematical modeling section, we present two basic equations that we have considered.

The concentration of bacteria at a distance r and time t is as follows [1]:

$$A(r,t) = C_{Tx}(r,t) \otimes f(r,t) \quad (1)$$

Where $C_{Tx}(r,t)$the concentration of bacteria molecules from transmitter end is, $f(r,t)$ is the input concentration of these molecules and $\otimes$ is the multi dimensional convolution operator

The input concentration $(f(r,t))$ is taken as proposed in [1]:

$$f(r,t) = \frac{N_A}{2\pi Dr} \operatorname{erfc}\left(\frac{r}{2\sqrt{Dt}}\right) \quad (2)$$

Where N_A is the releasing rate of bacterium molecules.

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3. Mathematical Modeling

3.1 Bacterial Concentration in Cylindrical Deployment:

From equation (2) the input concentration of the molecules is:

$$f(r,t) = \frac{N_A}{2\pi Dr}\,\mathrm{erfc}\left(\frac{r}{2\sqrt{Dt}}\right) \tag{3}$$

Taking the Fourier transform of $f(r,t)$ while keeping r constant and considering $\mathrm{erfc}\left(\frac{r}{2\sqrt{Dt}}\right)$ approaches 1 when as t increases in equation(3) , we get $F(\omega)$ as :

$$F(\omega) = \frac{N_A}{2j\omega\pi Dr} \tag{4}$$

The concentration of molecules from the transmitter at a distance ρ_{tx} and at initial time t_0 as in[13] :

$$C_{cyl}(\rho_{tx}, t_0) = \frac{1}{\sqrt{4\pi D(t-t_0)}} \times \sum_{m=1}^{\infty} \frac{J_0(\lambda_{0m}\sigma_{tx})J_0(\lambda_{0m}\sigma)}{N_{0m}}\, e^{-{\gamma_{0m}}^2(t-t_0)}u(t-t_0) \tag{5}$$

$$\text{Where } N_m = \frac{{\sigma_c}^2}{2}{J_n}^2(\lambda_{nm}\sigma_c) - J_{n-1}(\lambda_{nm}\sigma_c)J_{n+1}(\lambda_{nm}\sigma_c) \tag{6}$$

Taking the Fourier transform of (14) to get $C_{cyl}(f)$:

$$C_{cyl}(\omega) = \frac{e^{(-Dd^2-k_d-jdv)(t-t_0)}}{2\pi}\frac{J_0(\lambda_{0m}\sigma_{tx})J_0(\lambda_{0m}\sigma)}{N_{0m}} \times \frac{e^{-{\gamma_{0m}}^2 t_0}}{{\gamma_{0m}}^2+j\omega} \tag{7}$$

Where $k_d(s^{-1})$ is the reaction constant and σ is the particle density.
Since in frequency domain, convolution changes to product of the two terms we can write :

$$A_{cyl}(\omega) = C_{cyl}(\omega) \times F(\omega) \tag{8}$$

$$A_{cyl}(\omega) = \frac{e^{(-Dd^2-k_d-jdv)(t-t_0)}}{1}\frac{J_0(\lambda_{0m}\sigma_{tx})J_0(\lambda_{0m}\sigma)}{N_{0m}} \times \frac{e^{-{\gamma_{0m}}^2 t_0}}{{\gamma_{0m}}^2+j\omega} \times \frac{N_A}{2j\omega\pi D\rho} \tag{9}$$

Now we take Inverse Fourier Transform of eq[9] to get $A_{cyl}(\rho,t)$ as :

$$A_{cyl}(\rho,t) = \frac{N_A e^{(-Dd^2-k_d-jdv)(t-t_0)}J_0(\lambda_{0m}\sigma_{tx})J_0(\lambda_{0m}\sigma)e^{-{\gamma_{0m}}^2 t_0}}{2\pi D\rho N_{0m}} \int_{-\infty}^{\infty} \frac{1}{({\gamma_{0m}}^2+j\omega)j\omega}\, d\omega \tag{10}$$

$$A_{cyl}(\rho,t) = -\frac{N_A e^{(-Dd^2-k_d-jdv)(t-t_0)}J_0(\lambda_{0m}\sigma_{tx})J_0(\lambda_{0m}\sigma)e^{-{\gamma_{0m}}^2 t_0}}{2D\rho({\gamma_{0m}}^2 D)N_{0m}} \tag{11}$$

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when t approaches infinity t_0 also increases significantly such that the term $(t-t_0)$ approaches zero and we get the steady state concentration under cylindrical deployment as :

$$A_{cyl}{}^{*}(\rho,t) = -\frac{N_A J_0(\lambda_{0m}\sigma_{tx}) J_0(\lambda_{0m}\sigma) e^{-\gamma_{0m}{}^2 t_0}}{2D\rho(\gamma_{0m}{}^2 D) N_{0m}} \quad (12)$$

3.2.2 Rise Time for Bacteria in Cylindrical Deployment.

To evaluate rise time in we first find $A_r(\rho,t)$ as:

$$A_{r|cyl}(\rho,t) = \int_0^t A(\rho,t) \quad (13)$$

$$A_{r|cyl}(\rho,t) = -\frac{N_A J_0(\lambda_{0m}\sigma_{tx}) J_0(\lambda_{0m}\sigma) e^{-\gamma_{0m}{}^2 t_0}}{2D\rho(\gamma_{0m}{}^2 D) N_{0m}} \int_0^t e^{(-Dd^2 - k_d - jd\nu)(t-t_0)}\, dt \quad (14)$$

$$A_{r|cyl}(\rho,t) = \frac{N_A e^{-\gamma_{0m}{}^2 t_0}}{2D\rho(\gamma_{0m}{}^2 D) N_{0m}} J_0(\lambda_{0m}\sigma_{tx}) J_0(\lambda_{0m}\sigma) \left[\frac{e^{t_0}(e^{-t}-1)}{(Dd^2 + k_d + jd\nu)t_0}\right] \quad (15)$$

The rise time is expressed as follows [eqn 35, 1]

$$T_{r|cyl}(\rho,t) = \frac{A_r(\rho,t)}{A^*(\rho,t)} \quad (16)$$

$$T_{r|cyl}(\rho,t) = \frac{e^{t_0}(e^{-t}-1)}{\gamma_{0m}{}^2(Dd^2 + k_d + jd\nu)t_0} \quad (17)$$

3.2 Bacterial Concentration in Spherical deployments:

The input concentration from (4) is:

$$F(\omega) = \frac{N_A}{2j\omega\pi D\rho} \quad (18)$$

The concentration of molecules $C_{sph}(r,t)$ at a distance r from the transmitter bio-nanomachine and at time t as follows [13] :

$$C_{sph}(r,t) = \sum_{k=1}^{\infty} J_0(\lambda_k r) e^{-\lambda_k^2 D(t-t_0)} \quad (19)$$

Where D is the diffusion coefficient of the medium and symbol $J_n(.)$ represent the Bessel function of n^{th} order and first type for every positive value λ_n.
Taking the Fourier transform of (18) :

$$C_{sph}(\omega) = \frac{J_0(\lambda_k r) e^{-\lambda_k{}^2 D(t-t_0)}}{\lambda_k{}^2 D + j\omega} \quad (20)$$

Now in frequency domain the convolution changes into product of the terms:

$$A_{sph}(\omega) = C_{sph}(\omega) \times F(\omega) \quad (21)$$

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$$A_{sph}(\omega) = \frac{J_0(\lambda_k r)e^{-\lambda_k{}^2 D(t-t_0)}}{\lambda_k{}^2 D + j\omega} \times \frac{N_A}{2j\omega\pi Dr} \quad (22)$$

$$A_{sph}(r,t) = IFT[A(\omega)] \quad (23)$$

Therefore:

$$A_{sph}(r,t) = \frac{J_0(\lambda_k r)e^{-\lambda_k{}^2 D(t-t_0)}N_A}{2\pi Dr}\int_{-\infty}^{\infty}\frac{1}{(\lambda_k{}^2 D + j\omega)j\omega}d\omega \quad (24)$$

$$A_{sph}(r,t) = -\frac{J_0(\lambda_k r)e^{-\lambda_k{}^2 D(t-t_0)}N_A}{2rD^2\lambda_k{}^2} \quad (25)$$

When t approaches infinity, t_0 also increases significantly such that the term ($t-t_0$) approaches zero and we get the steady state concentration as :

$$A_{sph}{}^*(r,t) = -\frac{J_0(\lambda_k r)N_A}{2rD^2\lambda_k{}^2} \quad (26)$$

3.2.1 Rise Time for Bacteria in Spherical deployment.

Provided in (12) we will write $A_{sph}(r,t)$ as:

From (24) we have $A_{sph}(r,t) = -\frac{J_0(\lambda_k r)e^{-\lambda_k{}^2 D(t-t_0)}N_A}{2rD^2\lambda_k{}^2}$ (27)

$$A_{r|sph}(r,t) = \frac{J_0(\lambda_k r)N_A e^{-\lambda_k{}^2 Dt_0(e^{-t}-1)}}{2rD^2\lambda_k{}^2(-\lambda_k{}^2 D)t_0} \quad (28)$$

Following (15) Rise Time in spherical deployment will be given as :

$$T_{r|sph}(r,t) = \frac{e^{-\lambda_k{}^2 Dt_0(e^{-t}-1)}}{\lambda_k{}^2 Dt_0} \quad (29)$$

4. Results and Discussion

In this section the mathematical expressions proposed in section III have been simulated and quantified numerically for different parameters. In particular, Bacterial concentration and Rise time have been discussed numerically under spherical and cylindrical deployments. The parameters used are presented below in Table 1 with their Values

Parameter	Variable	Value
Diffusion coefficient	D	$10^{-9}m^2s^{-1}$

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Degradation reaction constant	k	$0,20\ s^{-1}$
Time	$t - t_0$	10 μs
Roots of Diffusion Equation	λ_k , γ_{0m}	500m , 200m,

Table 1 Parameters used in mathematical modeling

In **Fig. 2** Bacterial concentration as a function of distance ρ is presented. The parameter γ_{0m} which is the characteristic root of the diffusion equation is varied. Whereas, the release rate of bacteria molecules (N) is kept fixed.

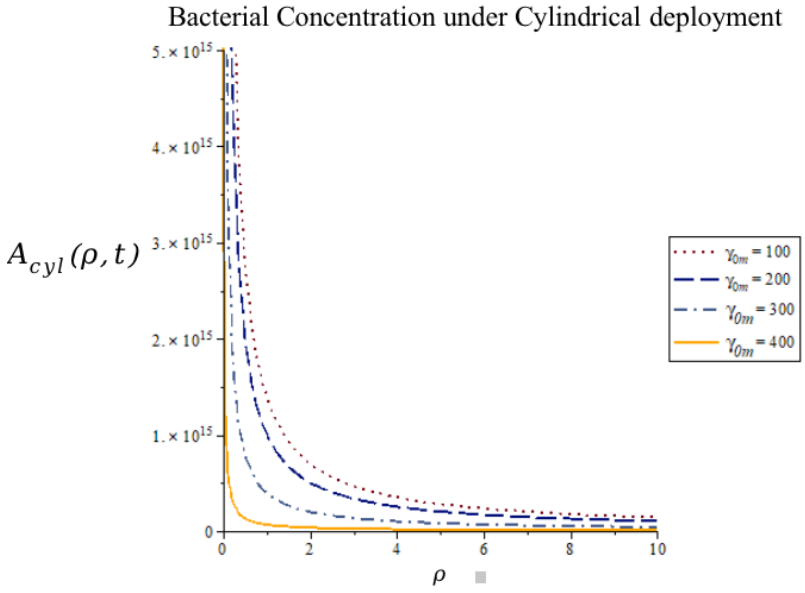


Figure 2
Bacterial Concentration under Cylindrical Deployment, when
$D = 10^{-9}$, $t - t_0 = 10\mu s$, $k = 0$, $jdv = 10$, $\lambda_{0m} = 500$ and $N = 1200$

For a given set of parameters, it is observed that as distance increases Bacterial concentration decreases. The maximum value of Bacterial concentration is at $\rho = 0$ (Transmitter end) and it approaches zero as ρ increases. Further for on increasing the value of γ_{0m} we observe that bacterial concentration decreases for any given value of ρ. In particular, for $\rho = 2$, the bacterial concentration is 0.85×10^{15}, 0.34×10^{15}, and 0.01×10^{15} for $\gamma_{0m} = 100$, 300 and 400 respectively.

Fig. 3 represents Bacterial concentration as a function of distance ρ under cylindrical deployment. The parameter N which is the rate of release of molecules. Whereas, the characteristic root of the diffusion equation (γ_{0m}) is kept fixed.

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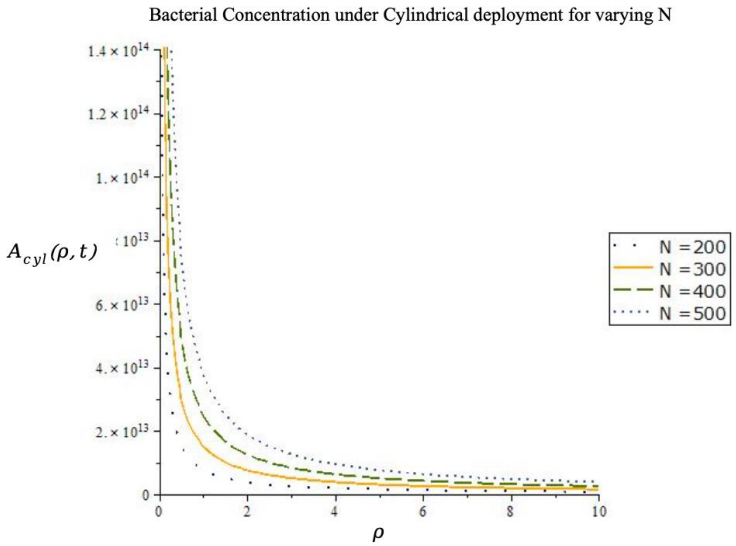


Figure 3
Bacterial Concentration under Cylindrical Deployment, when
$D = 10^{-9}$, $t - t_0 = 10\mu s$, $k = 0$, $jdv = 10$, $\lambda_{0m} = 500$ and $\gamma_{0m} = 200$

For a given set of parameters, it is observed that as distance increases Bacterial concentration decreases. Further for on increasing the value of N we observe that bacterial concentration increases for any given value of ρ. In particular, for $\rho = 1$, the bacterial concentration is 1.75×10^{13}, 1.86×10^{13}, and 1.98×10^{13} for $\gamma_{0m} = 100$, 300 and 500 respectively.

In Fig. 4 Bacterial concentration for Spherical deployment as a function of distance r is presented. The parameter $\lambda_{_}$ which is the characteristic root of the diffusion equation is varied. Whereas, the rate of release of molecules (N) is kept fixed.

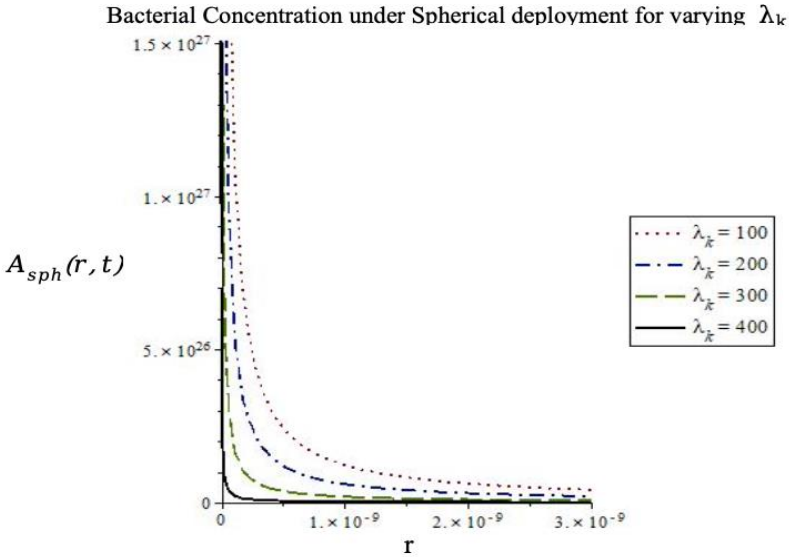


Figure 4
Bacterial Concentration under Spherical Deployment,
when $D = 10^{-9}$, $t - t_0 = 10\mu s$, and N=1200

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With the given set of parameters, it is observed from fig 4 that as distance increases Bacterial concentration decreases. The maximum value of Bacterial concentration is at $r = 0$ (Transmitter end) and it approaches zero as ρ increases (Receiver end). Further on increasing the value of λ_1 we observe that bacterial concentration decreases for any given value of r. In particular, for $r = 0.5 * 10^{-9}m$, the bacterial concentration is 2.42×10^{26}, 2.04×10^{26}, and 0.01×10^{26} for $\gamma = 100$, 300 and 400 respectively.

Fig. 5 shows the change in Bacterial concentration for Spherical deployment as a function of distance r. The parameter λ_1 which is the characteristic root of the diffusion equation is kept fixed and N is varied.

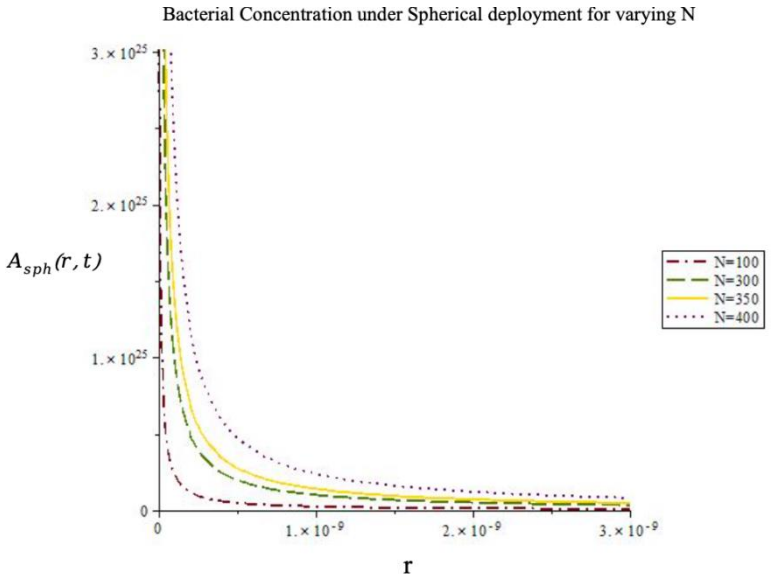


Figure 5
Bacterial Concentration under Spherical Deployment deployment,
when $D = 10^{-9}$, $t - t_0 = 10\mu s$, $\lambda_k = 500$

Here also it is observed that as distance increases Bacterial concentration decreases for a given set of parameters. Further on increasing the value of N we observe that bacterial concentration increases for any given value of r. In particular, for $r = 0.5 * 10^{-9}m$, the bacterial

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concentration is 0.17×10^{25}, 0.36×10^{25}, and 0.5×10^{25} for $N = 100$, 300 and 400 respectively.

In Fig 6 we have presented Rise Time for Spherical Deployment as a function of time 't'. The parameter λ_k is varied for $\lambda_k < 500$ and for $\lambda_k > 500$.

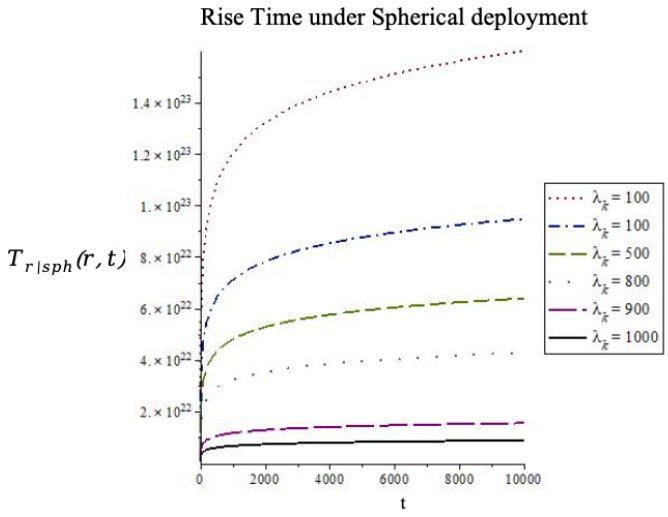


Figure 6
Rise Time under Spherical deployment for various values of λ_k and when $D = 10^{-9}$, $t_0 = 10\mu s$

We observe that when $\lambda_k < 500$ rise time approaches its steady value after a significant amount of time whereas when $\lambda_k > 500$ the steady state value is reached much faster. In particular for t=2000s and $\lambda_k = 1000, 500, 100$ the steady state value of rise time is $0.01 \times 10^{22}, 5.31 \times 10^{22}$ *and* 1.67×10^{23} respectively. There is a significant decrease in rise time for values of $\lambda_k > 500$ as compared to its value when $\lambda_k < 500$.

Fig 7 shows Rise Time for Cylindrical Deployment as a function of time't'. The parameter γ_{0m} is varied for $\gamma_{0m} < 500$ and for $\gamma_{0m} > 500$.

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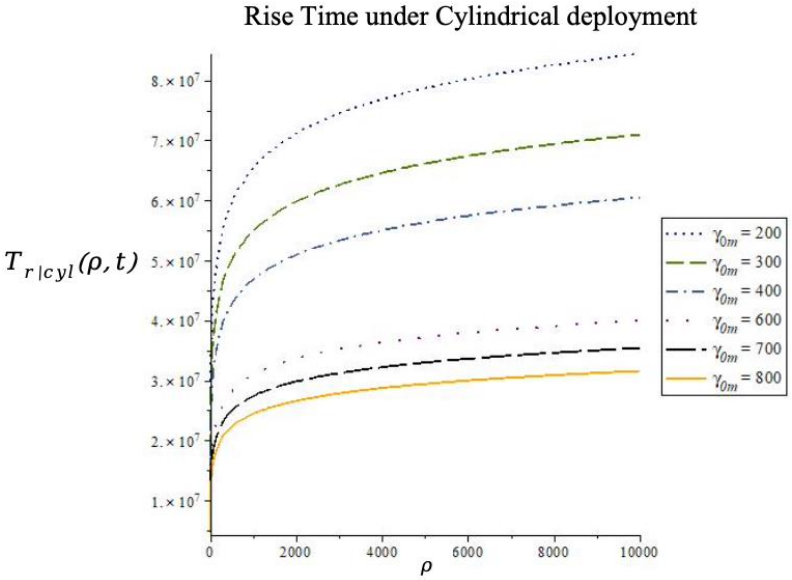


Figure 7
Rise Time under Cylindrical deployment for various values of λ, when D = 10^{-9}, t_0 = 10μs, k = 0, d = 0.1 and jdν=10

From the above graph it is observed that when $\gamma_{0m} < 500$ rise time approaches its steady value with some delay whereas when γ_{0m} > 500 the steady state value is reached faster. In particular for t=2000s and $\lambda_k = 800, 600, 300$ the steady state value of Rise Time is $2.64 \times 10^7, 3.58 \times 10^7$ *and* 6.67×10^7 respectively. Therefore there is a significant decrease in Rise Time for values of $\lambda_k > 500$ as compared to its values when $\lambda_k < 500$.

5. Conclusion

Analytical expressions for bacterial concentration and rise time under different biological deployments such as, Biological Cylindrical Deployment (BCD) & Biological Spherical Deployment (BSD) have been presented. Different physical parameters such as, diffusion coefficient (D), degradation reaction constant (k), initial time duration (t_0) roots of diffusion equation (λ_k/γ_{0m}), Bacterium release rate (N) and distance between Tx & Rx (r/ρ) have been utilized to quantify the effect of deployments on different performance measures. It has been observed that Bacterium concentration decreases with an increase in time duration of release. It is noteworthy to mention that diffusive scenarios such as sub-diffusion or super-diffusion play vital roles in the overall DMC system. Inclusion of other performance measures like information rate, channel response; fall time etc. under different deployments such as BCD or BSD is an instant future aspect of the proposed end to end model of BC.

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DMC APPROACH FOR BACTERIAL PROPAGATION OVER SPHERICAL BIOLOGICAL DEPLOYMENT

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Abstract

Diffusive Molecular Communication (DMC) is the most common of Molecular Communication (MC) which can be utilized to model bacterial propagation within different biological deployments. Out of different biological deployments, Spherical Biological Deployments (SBD) is the most versatile for representing several biological tissues or organs. In this research, different performance metrics have been analysed over SBD followed by presenting analytical expressions. Analytical expressions for binding probability (P_b), non-binding probability (P_{nb}), Evade probability ($P_e(y)$) and the probability of binding rate at y ($P_b(y)$) have been presented. The numerical quantification shows perfect agreement with the theoretical background.

Keywords

Diffusive Molecular Communication, Bacterial Propagation, Spherical Biological Development, Mucus Flow, Probability Sensitivity Analysis

Introduction

The field of MC engages in the creation of cutting-edge technology that leverages a network of micro and nanoscale devices embedded within the human body [1-2]. These devices can harness natural cellular and tissue signalling, facilitating interaction and communication within the human physiological environment. This burgeoning field holds significant promise in addressing contemporary and anticipated pandemics, offering valuable insights into bacterial properties and characteristics, while also paving the way for the development of innovative

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treatments [1-2]. Bio-nano machines (BNMs) are crucial for disease detection within the human body, forming the Internet of Bio-Nano Things (IoBNT). Authors have explored noise challenges in Molecular Nano Communication (MNC) and Electromagnetic Nano Communication (EMNC) while addressing applications in oncology, ontogenetic, and defence [3-4]. They provide insights into the evolving MNC landscape, covering challenges tied to noise, interference, and fading in system design and development.

DMC emerges as an exceptionally advantageous technique for facilitating nano-scale communication in healthcare-related biological environments [5]. The author investigates the implementation of physical layer security in DMC, exploring Secrecy Capacity under different biological deployments and emphasizing the significant influence of the authentic receiver's distance on the value of Secrecy Capacity [6]. The author of this paper also worked for healthcare applications, diffusive molecular communication (DMC) is explored within a biological spherical environment (BSE) in this paper, inspired by sphere-like structures within the body. The model assumes the sphere's inner surface is covered by receptors for irreversible reactions with molecules, forming a bounded biological environment [7]. Various researchers have explored the potential of MC to introduce and utilize a network of micro- and nanoscale devices for intricate sensing and actuation within the human body [8, 9]. Emphasizing the utilization of the body's inherent cellular and tissue signalling, these devices hold promise for effective interaction and communication with the human body. A key advantage lies in the potential to enhance the compatibility of implantable systems by integrating systems and synthetic biology with communication system engineering [8, 9].

Our study focuses on unravelling the dynamics of bacterial transmission within a simplified model, tracing the route from the nasal cavity to various human organs such as lungs, kidneys, and liver, while considering biological spherical deployments. However, the author [10] has given the necessity of understanding SARS-CoV2 transmission dynamics for developing prevention and treatment techniques. The study models virus transmission through the respiratory tract, highlighting the influence of mucus flow rate on virus migration to various respiratory regions. This information is crucial for comprehending SARS-CoV2 effects on diverse populations with varying mucus flow rates and ACE2 receptor concentrations. In [11] authors have discussed nanomachine-to-nanomachine communication for spherical absorbing receivers. This work presented that signal characteristics like pulse peak time and pulse amplitude are affected by degradation. Authors have analytically shown and modelled signal-shaping achievement through degradation.

The author [12] presents the role of molecular signalling in multicellular organisms and presents a study on the superior energy efficiency of bacteria mobile relays for information delivery over long distances in molecular communication systems, with broad implications for biological understanding and synthetic biology communication design. Till now all this work has been done we have evaluated different measures over a spherical system using the

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concentration density of informed bacteria at any point in time and space dependent on the diffusion coefficient. Shown the mathematical modelling and Simulation Graph for different expressions like probability rate at y and Evade probability.

Molecular communication is a form of communication at the micro-scale where bacterial propagation within the human body plays a pivotal role. Bacterial propagation encompasses the intricate mechanisms through which bacteria multiply and disseminate within a host organism. This phenomenon is pivotal in comprehending the dynamics of microbial infections and the complex interplay between bacteria and their host [13]. Bacterial propagation can manifest through diverse processes, including cellular division, horizontal gene transfer, and transmission from one host to another. The liver is highly exposed to gut bacteria and their metabolites [14]. Bacteria employ molecular signalling to coordinate their activities, respond to changes in the host environment, and interact with the host's immune system. The immune system deploys signalling molecules, such as cytokines, to initiate an immune response when it detects the presence of bacteria. These dynamic processes encompass mechanisms like chemotaxis for bacterial motility, adhesion to host tissues, and biofilm formation across various bodily regions [15].

Authors in [16] have considered bacterial communication nanosystems for multiple sources and proposed a mathematical model to explore message dissemination through bacterial communication in biologically inspired systems that agrees with Fick’s law of diffusion. The paper [17] has considered DMC for cylindrical-shaped blood vessels. The system model assumed that the internal surface boundary of cylindrical structure is covered with biological receptors. Error probability and the Green function of diffusion have been derived. The paper also shows that a considered system model can mitigate the interference as well. Authors in [18] have discussed the application of molecular communication for viral infection research. The paper [19] has analysed Radiation absorption noise for molecular communication. The authors have given the probability density function. BP is used in disease detection and treatment such as QS-based synthetic bacterial therapy treatment of diseases [20]. Bacterial biofilms, widespread in diverse environments, including the human body, play pivotal roles in pathogenesis and host health. This review explores their occurrence, impact, and diversity within the body, influencing health in both homeostatic and dyspeptic conditions [21]. However, the author shows recent evidence suggesting human cancers harbour microbial ecosystems impacting cancer functions. Examining intratumoral bacteria reveals molecular activities, colonization, and their implications for tutor behaviour and treatment [22]. Moreover, the author has given way for utilizing bacteria and bacterial derivatives to enhance targeted medicine delivery for viral infections, aiding antiviral immunity despite physical barriers. Advancements include genetic and chemical modifications for safer, more effective vaccinations against viruses like SARS-CoV-2, hepatitis, influenza, and Ebola [23].

Major contribution

The author’s contributions to this manuscript are summarized as follows:

- Spherical Biological Deployment schemes are used to present an analysis of Bacteria binding rate in the human gut system.

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- Presents analytical expressions of Probability of binding, Probability of not-binding, Evaded Probability, and Probability rate at the end under BSD schemes.
- Analyses the effect of various parameters such as; Bacteria Binding rate, Mucus flow rate, time (t), Number of initial Bacteria (N), Relative speed between two bacteria (V), Radius of the infected bacteria (R) and Simulation area(A) for DMC system under BSD schemes.

The paper is organized as follows: The following section introduces the system model considered for analysis. The next section includes proposed analytical expressions for BP over the SBD. The fourth section includes numerical discussions and the conclusion of the work is given in the last section.

System Model

In the framework of molecular communication, this study delves into the intricate dynamics governing bacterial propagation within the human body. At the micro-scale, bacteria utilize signalling molecules to orchestrate their activities, adapting to shifts in the host's environment and engaging with the immune system. Simultaneously, the host's immune system deploys its own signalling molecules, such as cytokines, to activate immune responses upon detecting bacterial presence, profoundly influencing the dynamics of bacterial propagation.

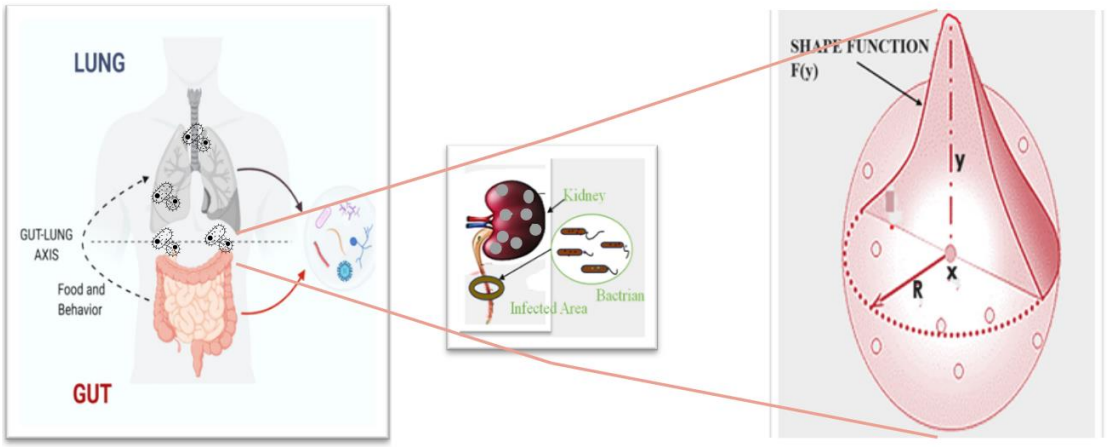


Fig.1. System Model

Recently, authors have presented viral transmission in the respiratory system for rectangular deployment. In contrast, this research work presents various analytical expressions for bacterial propagation following the DMC approach under spherical deployment. In this paper we analysed the Bacterial propagation over Spherical shapes within specific organs, such as the lungs and liver, involving unique molecular communication pathways. The system model is shown in Fig. 1. For example, bacteria in the lungs may utilize surfactants and respiratory mucosal signalling molecules, while the liver may rely on hepatocyte signalling. To determine the concentration of bacterium, we account for the effects of Brownian motion with drift. This

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mathematical framework, derived from Brownian motion with drift, takes into account three spatial dimensions: the y-axis, representing the distance from the entrance of the nasal cavity; the x-axis, denoting the distance from a longitudinal reference point; and the z-axis, representing the thickness or width of the mucus layer and t represent the time. The expression of Concentration (C) is represented as:

$$C(x, y, z, t) = \frac{2e^{-(\frac{y^2}{4Dt})}}{(4Dt)^{\frac{3}{2}}} \quad (1)$$

Where D = Diffusion Constant.

Similarly the expression for receptor Concentration per unit area at y represented by F(y) is given as

Where F(y) defines the different parameters like:

$$F(y) = \frac{r\, e^{\frac{rz}{c}}}{8\, RVe\, (g)^2} log\left(\frac{4r\, e^{\frac{rz}{c}}}{(g)^2}\right) + \frac{N}{A\,(g)} \quad (2)$$

R - Radius of the bacterial infection area.

N – No of Bacteria

A – Simulation area

z – Represent the function of y i.e. y – ys

This description characterizes the density of informed/infected bacteria concerning space and time. Bacteria disperse via random walk trajectories throughout the simulation area. To avoid misunderstanding, clarify that diffusion velocity differs from infection velocity, influenced by interactions [4]. Regarding the expressions for F(y) and C, we've derived the probabilities of blinding and not blinding, the likelihood of the Bacteria evading all ACE2 receptors, and the binding rate. This analysis also extends to the number of bacteria, and bacteria distribution in the human stomach and encompasses the simulation of the dynamics associated with an individual bacterium.

Proposed Analytical Expressions for BP over SBD

List of abbreviations

MC - Molecular Communication
DMC - Diffusive Molecular Communication
SBD - Spherical Biological Deployments
BP - Bacterial Propagation
BNMs - Bio-nano machines
IoBNT - Internet of Bio-Nano Things

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MNC-Molecular Nano Communication
EMNC - Electromagnetic Nano Communication
BSE - Biological spherical environment
SARS-CoV2 - Acute Respiratory Syndrome-Coronavirus 2
ACE2 - Angiotensin-Converting Enzyme
TA - Transmission Attractant
RA - Reception Attractant
DA - Diffusion Coefficient

In our modelling approach, we consider the TA and RA as continuously released substances. Both exhibit the same DA and are released at a uniform rate (NA [mol/s]). The release process is conceptualized as a step function, marked by its sudden and instantaneous nature, capturing its immediate onset and rapid propagation. According to Fick's second law of diffusion, the impulse response of this process, denoted as C (x, y, z, t), can be analysed at a specific location (x, y, z) within a 3D medium, with the parameter of time (t):

$$C(x, y, z, t) = \frac{e^{-(\frac{y^2}{4Dt})}}{4(Dt)^{\frac{3}{2}}} \quad (3)$$

The probability of binding to a single ACE2 receptor in the segment with length Δy becomes:

$$P_b = \frac{\lambda\ e^{-(\frac{y^2}{4Dt})}}{4Kv_m(Dt)^{\frac{3}{2}}} \quad (4)$$

By the expression to determine the non-binding to a single ACE2 receptor in the segment with length Δy becomes:

$$P_{nb} = 1 - P_b \quad (5)$$

Substitute the equation [2] in equation [3], to determine the non-binding to a single ACE2 receptor in the segment with length Δy becomes:

$$P_{nb} = 1 - \frac{\lambda\ e^{-(\frac{y^2}{4Dt})}}{4K\ v_m(Dt)^{\frac{3}{2}}} \quad (6)$$

One interesting observation about the function of the traveling wave solution F(y) is that the density of informed bacteria at any point in time and space is independent of the diffusion coefficient. (There is no diffusivity term present in the equation.):

$$F(y) = \frac{r\ e^{\frac{rz}{c}}}{8\ RVe\ (g)^2} log\left(\frac{4r\ e^{\frac{rz}{c}}}{(g)^2}\right) + \frac{N}{A\ (g)} \quad (7)$$

There are given the function of r, c, z, and g become as

$$r = \frac{2RVeN}{A}, c = 2\sqrt{\frac{2RVeN}{A}}, z = x - ct,\ g = 1 + e^{\frac{rz}{c}}$$

Where,

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Ve = relative speed between two bacteria

D = diffusion coefficient

c = wave speed

x = distance $y - \Delta y$ ($\Delta y$is the initial infection source point)

By substituting the value z in the given of g expression then F(y) becomes:

$$F(y) = \frac{N}{Ag}\left(\left(1 - \frac{1}{g}\right) log\, \frac{1}{g} + 1\right) \quad (8)$$

If the ACE2 concentration per unit area at y is f(y), then the number of ACE2 receptors, n(y), in the patch of length Δy becomes:

$$n(y) = 2\pi r(y)F(y)\Delta y \quad (9)$$

The probability of the Bacteria evading all ACE2 receptors in the same patch, P_e (y), is expressed as:

$$P_e\,(y) = (P_{nb}\,)^{n(y)} \quad (10)$$

$$P_e\,(y) = \left(1 - \frac{\lambda\, e^{-(\frac{y^2}{4Dt})}}{4Kv_m(Dt)^{\frac{3}{2}}}\right)^{2\pi r(y)F(y)\Delta y} \quad (11)$$

we use the first order truncation of the binomial expansion, i.e., $(1 - x)^n = 1 - nx$

for |nx|<< 1, which holds due to NA being much larger than any other value in (9). This assumption is especially effective for Δy → dy, expressed as:

$$P_e\,(y) = \left(1 - \frac{\lambda\, e^{-(\frac{y^2}{4Dt})}}{4Kv_m(Dt)^{\frac{3}{2}}}\right)(2\pi r(y)F(y)\Delta y) \quad (12)$$

From (10), we reach the rate of binding in the patch of length Δy as:

$$P_b\,(y) = 1 - P_e(y) \quad (13)$$

$$P_b\,(y) = \left(\frac{\lambda\, e^{-(\frac{y^2}{4Dt})}}{4K\, v_m(Dt)^{\frac{3}{2}}}\right)(2\pi r(y)F(y)\Delta y) \quad (14)$$

Further, simplify the Equation [12], substitute the F(y) from Equation [6];

$$P_b\,(y) = \left(\frac{\lambda\, e^{-\left(\frac{y^2}{4Dt}\right)}}{4K\, v_m(Dt)^{\frac{3}{2}}}\right) * (2\pi r(y)\Delta y) * [\frac{N}{Ag}\left(\left(1 - \frac{1}{g}\right) log\, \frac{1}{g} + 1\right)] \quad (15)$$

Where,

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$$g = 1 + e^{\frac{r\{(y-\Delta y)-ct\}}{c}}$$

Due to the elemental value of y, Δy will be neglected for Simulation of $P_b\,(y)$.

Also the surface area S can be expressed as: S=2πr(y).y

$$P_b\,(y) = \left(\frac{S\,\lambda\; e^{-\left(\frac{y^2}{4Dt}\right)}}{4kyv_m(Dt)^{\frac{3}{2}}}\right) * \left[\frac{N}{Ag}\left(\left(1-\frac{1}{g}\right) log\,\frac{1}{g}+1\right)\right] \quad (16)$$

Numerical Discussion

In this section, we present the Numerical analysis and discussion of DMC Approach for BP over SBD. From the Mathematical demonstration, we got different equations for different expressions that as Probability of blinding (P_b), Probability of not blinding (P_{nb}), Evade probability in the segment ($P_e(y)$) and Blinding rate at y $\{P_b\,(y)\}$, by considering the various values expectancy for this expression under different parameters that is Bacteria Binding rate (λ), Mucus flow rate (v_m), no. of initial Bacteria (N), Relative speed between two bacteria (V) and Simulation area(A).
It is observed that an increase in this mucus flow rate results in a decrease in evasion probability and probability rate at y. Whereas, an increase in receptor-bacteria binding rate results in increased evasion probability and probability rate at y. Similar observations are made for other parameters. We have taken the X axis as the time and the Y axis as the different mathematical expressions. The software used for drawing graphs and figures is MATLAB R2016a.

In Fig. 2., Analysis of values of the v_m and A is shown, specifically we can see that for different values of v_m such as 15 $\mu m s^{-1}$, 25 $\mu m s^{-1}$, 35 $\mu m s^{-1}$ and similarly for the different value of A such as 0.5 μm, 2.5 μm, 4.5 μm results in decrease in $P_e\,(y)$. Because our representation says when we increase the value of mucus flow rate the evaded probabilities will cause diseases due to mucus present in the body which will affect the concentration of Bacteria's so the avoidance will be less.

In Fig.3, Analysis of values of the N and λ is shown, specifically we can see that for different values of λ such as 3 $M^{-1}s^{-1}$, 6 $M^{-1}s^{-1}$, 9 $M^{-1}s^{-1}$and similarly for the different values of N such as 15, 20, 25 results in increase in $P_e\,(y)$. However for λ has some threshold value in which for some particular value it has been increases after that when no. of receptor-Bacteria binding rate has been increased which results in decreased in $P_e\,(y)$.

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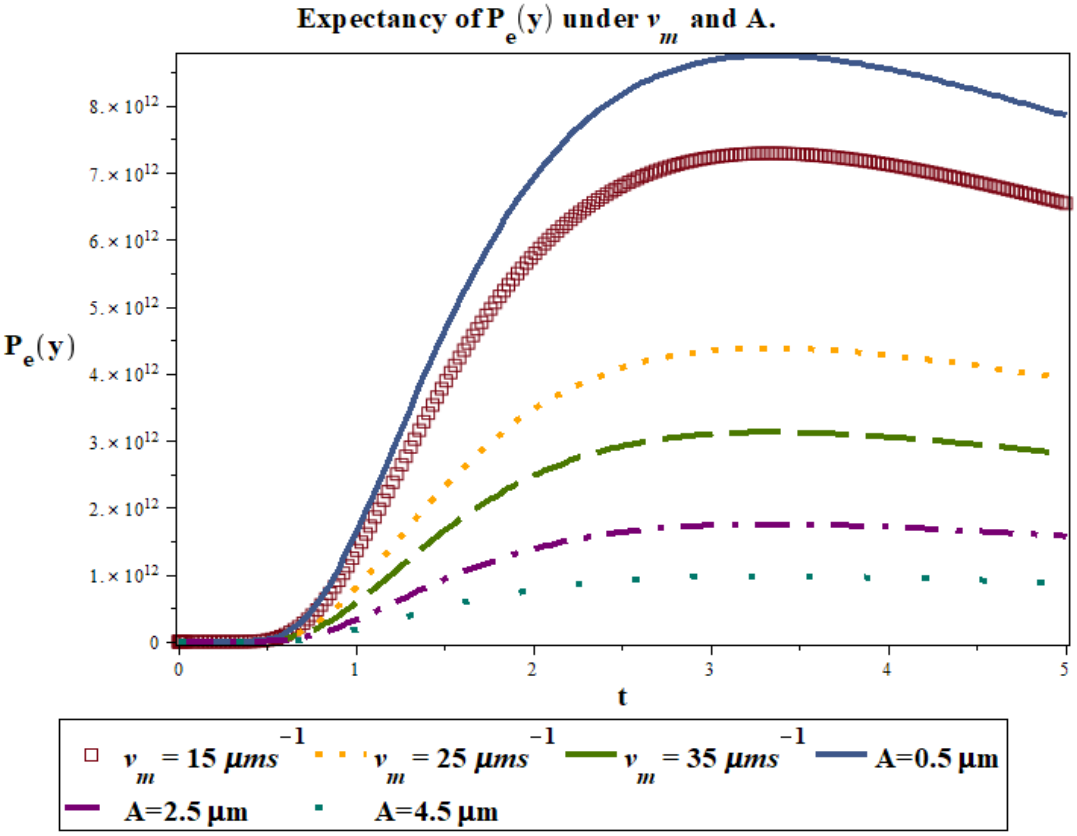
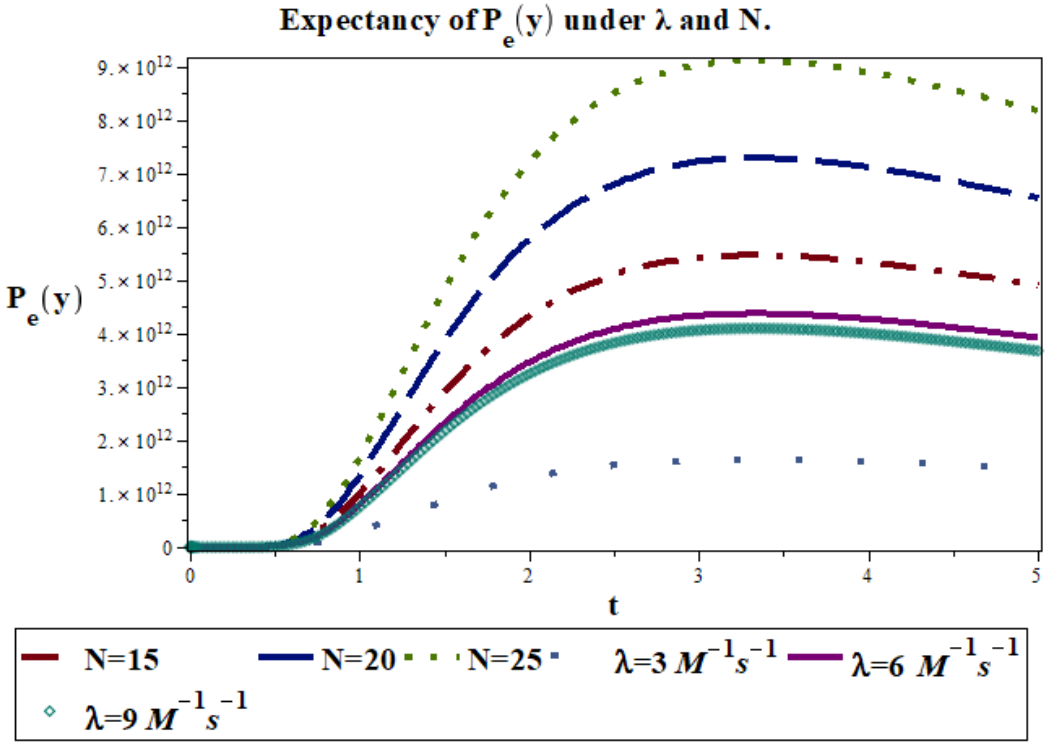


Fig. 2. Expectancy of $P_e(y)$ with respect to v_m and A.



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Fig. 3. Expectancy of $(P_e(y))$ with respect to N and λ .

In Fig.4. we conducted an analysis of the while considering various values of the N and A, specifically we can see that for different values of N such as 15, 20, 25 and similarly for the different value of A such as 1.5μm, 2.5 μm, 3.5μm. The results shows decease in $P_e\ (y)$ when we increase the Simulation area because increase in receptor so the avoidance will less. However, the observation of N is the same as mentioned in Fig. 3.

In Fig. 5, Analysis of values of $P_e(y)$ while considering various values of the V, v_m and λ , specifically for V=0.01ms^{-1} , 0.5 ms^{-1} results in increase in $P_e\ (y)$. Our findings indicate that when the increase in relative velocity between two Bacterias the absolute velocity also increases due to which there chances of contract between the Bacteriaes is less so that's why the evade probability has been increased. The observation for λ and v_m are given in fig. no. 2 and 3.

In Fig. 6, we conducted an analysis of the while considering various values of the N andλ, specifically we can see that for different values of λ such as 7 $M^{-1}s^{-1}$, 7.5 $M^{-1}s^{-1}$, 8 $M^{-1}s^{-1}$and similarly for the different values of N such as 15, 20, 25 results in increase in $P_b(y)$.

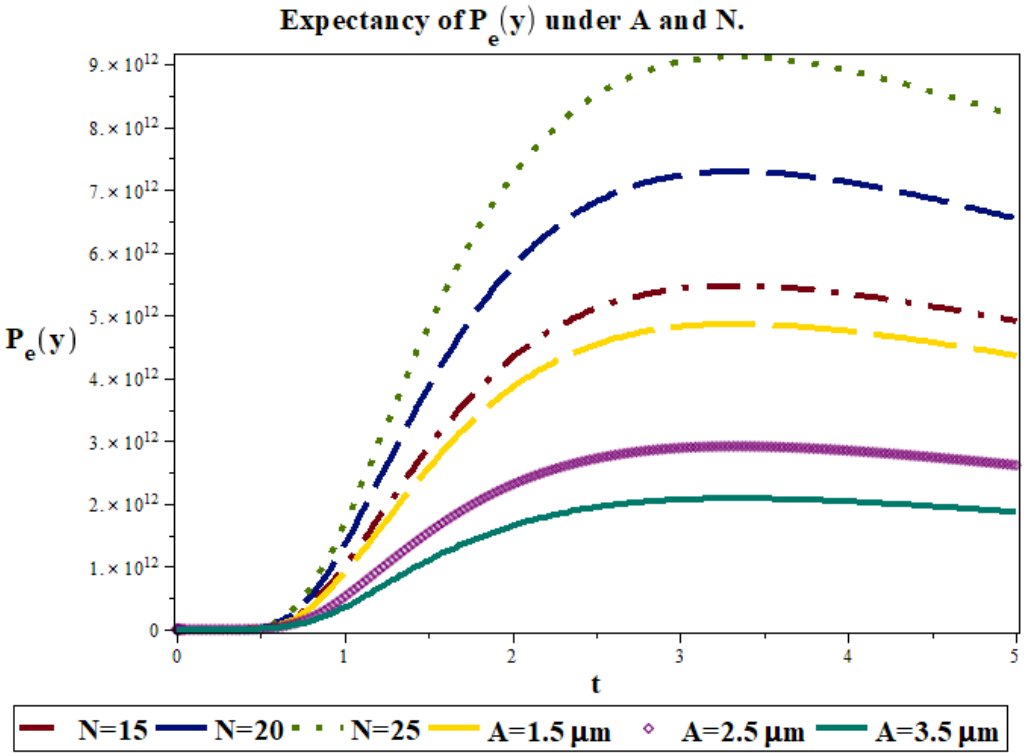


Fig. 4. Expectancy of $P_e(y)$ with respect to N and A.

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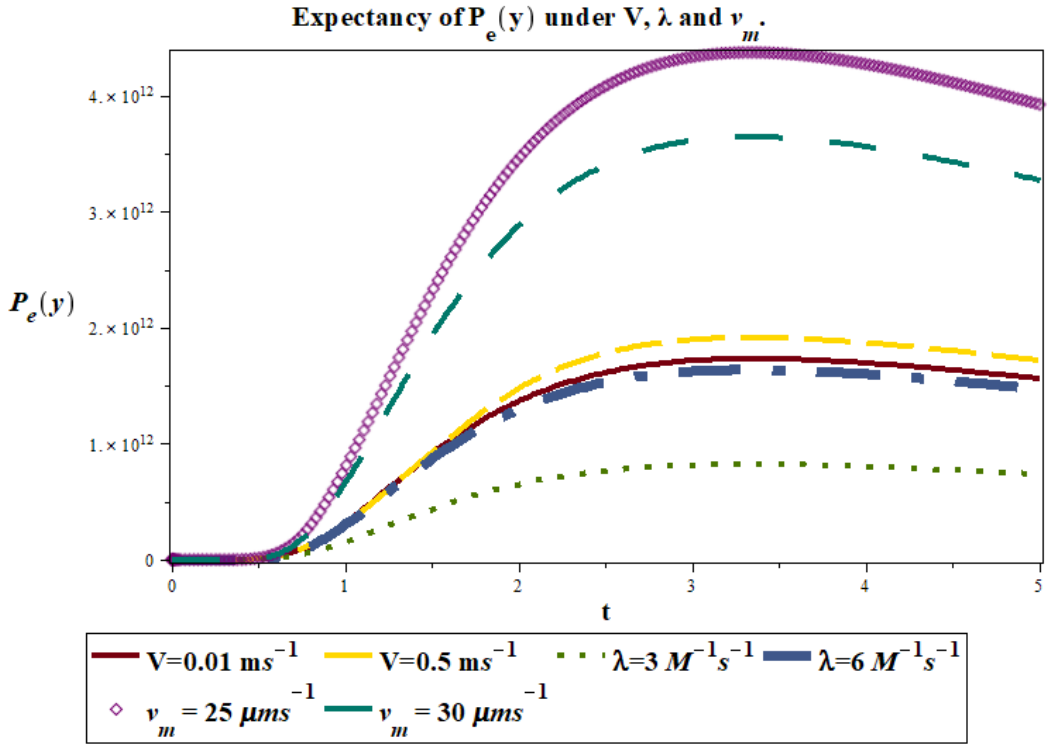


Fig. 5. Expectancy of $P_e(y)$ with respect to V λ and v_m.

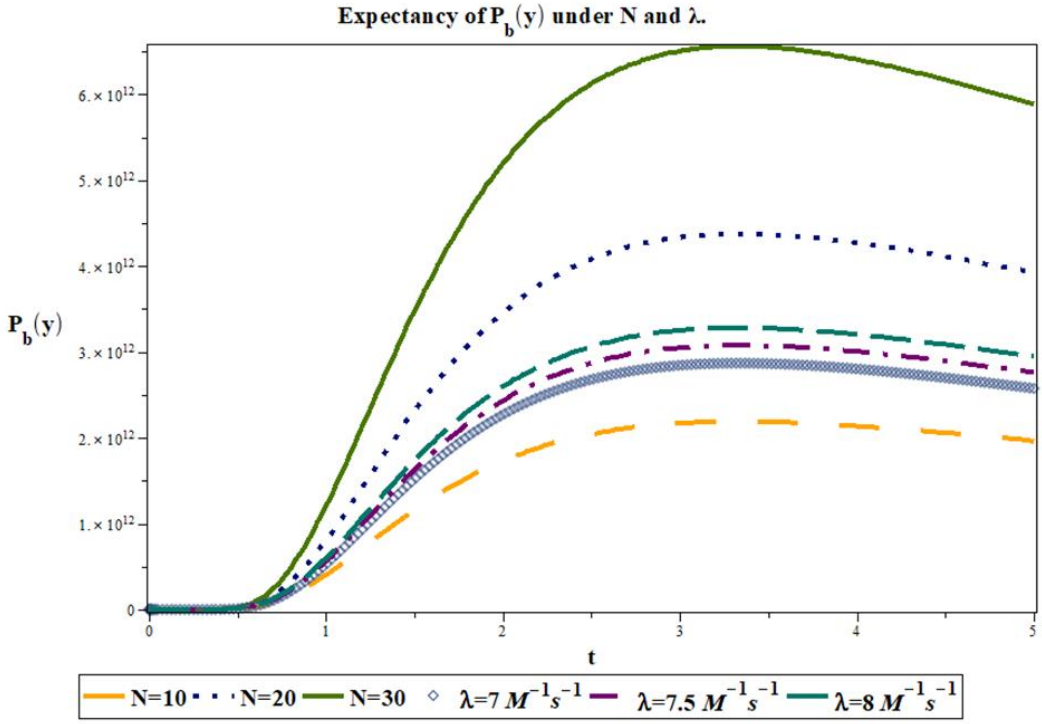


Fig. 6. Expectancy of $(P_b(y))$ with respect to N and λ .

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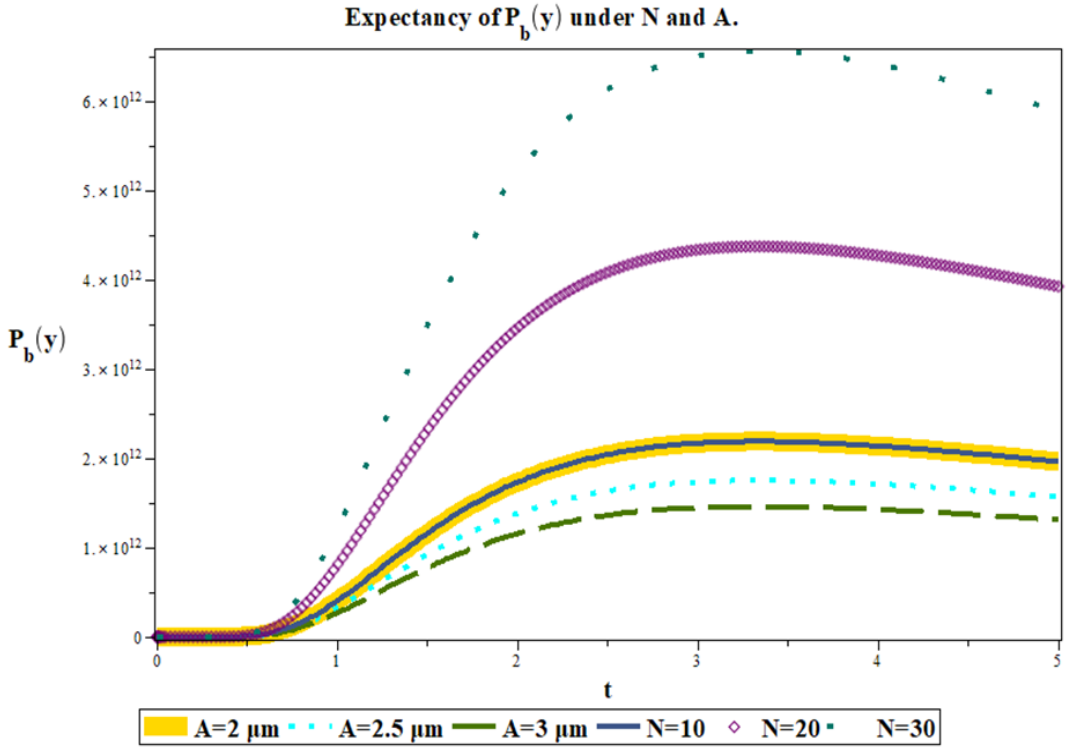


Fig. 7. Expectancy of $P_b(y)$ with respect to A and N.

In Fig. 7, we conducted an analysis of the $P_b(y)$ while considering various values of the N and A, specifically we can see that for different values of N such as 10, 20, 30 and similarly for the different value of A such as $2\mu m$, 2.5 μm, $3\mu m$. The results shows decease in $P_b(y)$. Physical representation when we increase the Simulation area because increases in receptor for constant no. of Bacterias so the decrease in$P_b(y)$. However for observation of N is that when we increase the value of N the $P_b(y)$ increases. It is important to mention that when the N =15, A = 2 μm has same value for A=1.5μm, N=10.

In Fig. 8, we conducted an analysis of the while considering various values of the v_m and A, specifically we can see that for different values of v_m such as 20 $\mu m s^{-1}$, 25 $\mu m s^{-1}$, 30 $\mu m s^{-1}$ and similarly for the different value of A such as 1.5 μm, 2.5 μm, 3.5 μm results in decrease in $P_b\ (y)$. Because our representation says when we increase the value of mucus flow rate the probability rate at y will cause diseases due to the initial receptor before y which will affect the concentration of Bacteria.

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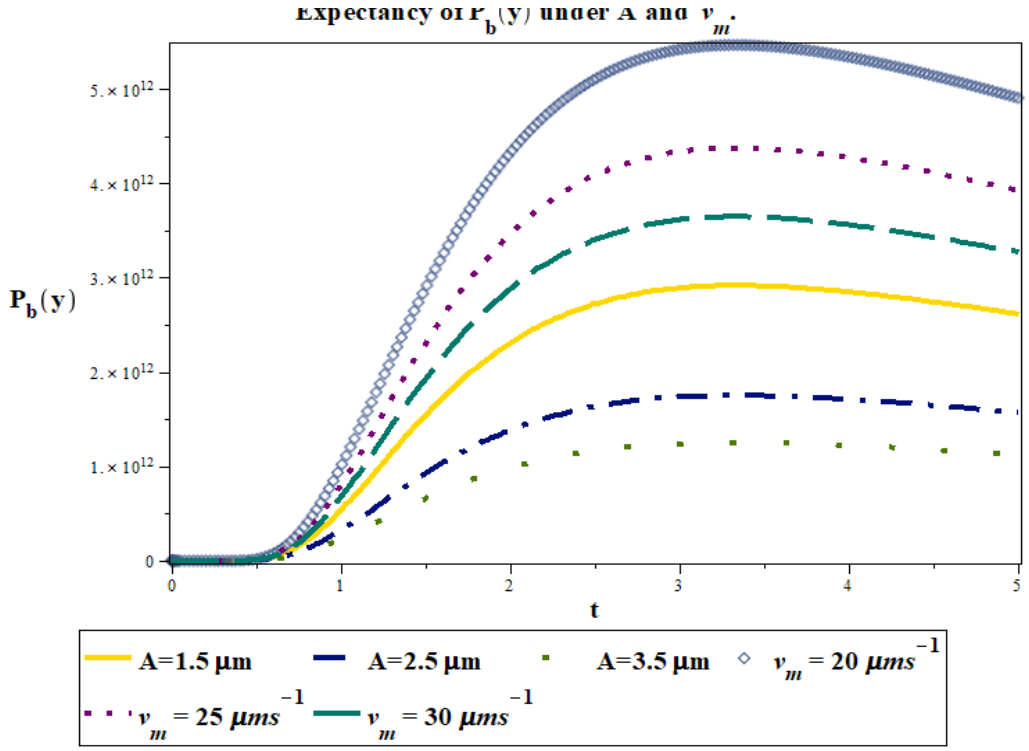


Fig. 8. Expectancy of $P_b(y)$ with respect to v_m and A.

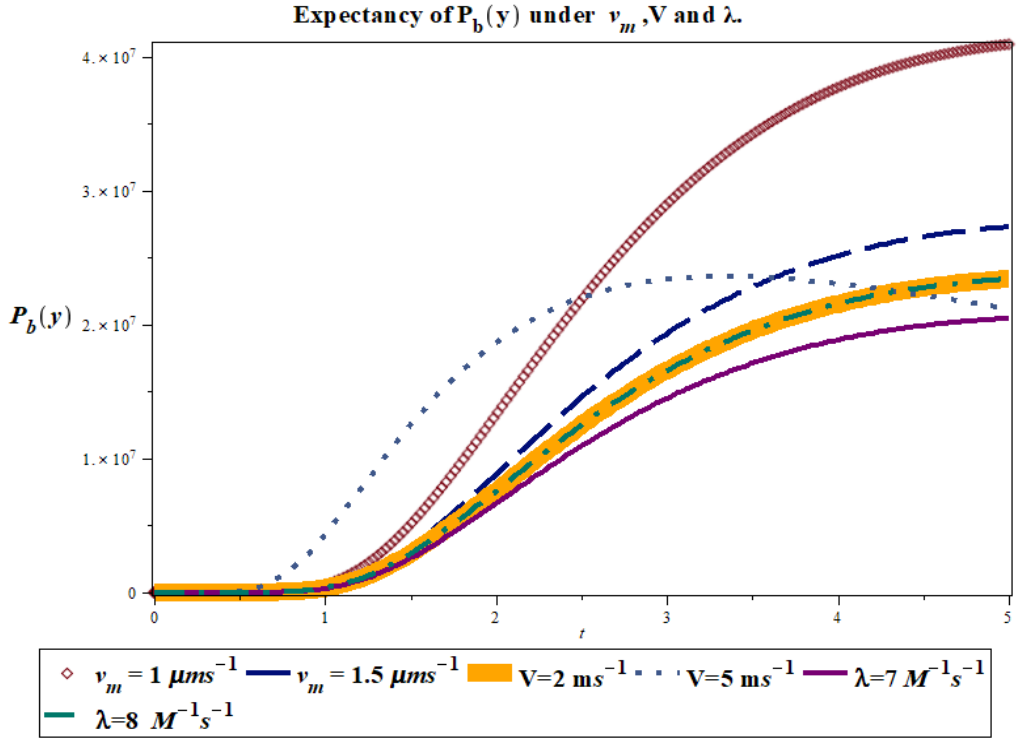


Fig. 9. Expectancy of $P_b(y)$ with respect to V λ and v_m.

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In Fig.9., we conducted an analysis $P_b(y)$ of the while considering various values of the V, v_m and λ , specifically for V=2ms^{-1} , 5ms^{-1} results in increase in P_b (y). Our findings indicate that when the increase in relative velocity between two Bacterias the absolute velocity also increases due to which there chances of contract between the Bacteriaes is less so that's why the evade probability has been increased. The observation for λ and v_m are given in fig. no. 2 and 3. It is important to mention that when the V =2 ms^{-1}, λ = 7 $M^{-1}s^{-1}$has same value for V=5ms^{-1}, λ = 8 $M^{-1}s^{-1}$.

Conclusion

In this paper, we propose bacterial propagation over spherical shapes within specific organs, such as the lungs and liver, involving diffusive molecular communication pathways by considering various values for the parameters: bacteria Binding rate (λ), mucus flow rate (□□), number of initial bacteria (N), relative speed between two bacteria (V), and simulation area (A). The simulated results align perfectly with the theoretical background. It is observed that an increase in mucus flow rate results in a decrease in evasion probability and probability rate at y, whereas an increase in receptor-bacteria binding rate results in increased evasion probability and probability rate at y. Similar observations are made for other parameters. As the next step, bacterial propagation can be introduced to more complex scenarios such as biological cylindrical deployment, biological rectangular deployment, etc. Moreover, the study focuses on specific organs. Later works may affect the entire human gut with bacteria's distribution and actual number of bacteria reached at the end. Additional future work might include virus propagation with respect to diffusive molecular communication inside human body organs in order to further detect diseases caused by harmful viruses and bacteria. Optimization of other parameters, such as the radius of the infected bacteria and wave speed, could be explored.

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INVESTIGATION OF SECRECY OUTAGE PROBABILITY OF NOMA SYSTEM OVER MIXTURE GAMMA FADING CHANNEL

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Abstract

Non Orthogonal Multiple Access (NOMA) approach is being developed as better multiple accesses for 6G and beyond. It provides enormous band width that can be utilized to accommodate ever growing need of data rate. However, outage probability, which is a basic performance metric of any wireless system, highly depends on fading of the wireless link. On the other hand, Mixture Gamma (MG) fading distribution is one of the most generic fading models. Therefore, in this research secrecy outage probability over MG fading distribution has been analyzed followed by presenting a new analytical expression of it. Simulation shows agreement with theoretical background.

Keywords

Non-orthogonal multiple access (NOMA), Mixture Gamma (MG), Secrecy Outage Probability, Data Rate and Generic Fading.

I. Introduction

NOMA stands out as a promising radio access technique for the next generation of wireless communications, offering advantages over traditional methods like OFDMA. It provides increased spectrum efficiency, lower latency with high reliability, and supports massive connectivity by serving multiple users using the same resource in terms of time, frequency, and space. Considering the rapid growth in wireless services and smart devices, Next Generation Multiple Access (NGMA) design must account for massive access and short packet transmission. NOMA, operating in code and power domains and compatible with single or multi-carrier transmission, emerges as a key solution to meet the escalating demand for data traffic in future mobile communication systems. On a different note, Free Space Optical (FSO) communication is a rapidly advancing technology with the capacity to handle high data rates and significant information capacity, serving as an alternative to fiber optics technology. In many instances, FSO systems offer the only viable

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option for establishing a connection over a line-of-sight (LOS) path between the source and destination. As link between transmitter and receiver is open media, therefore, it is prone to different channel impairments. Cooperative relaying is a wireless communication technique that promises to improve throughput and energy efficiency. Through cooperative communication, where a device sends a data signals to a destination, and a third device intercepts and forwards the signal to its intended target. This process involves multiple relay nodes working together to assist a source in transmitting information to its destination, effectively creating a virtual antenna array. The relays contribute to diversity by generating multiple copies of the signal of interest. The collaborative approach enhances the overall performance and reliability of signal transmission. The mixture gamma distribution is a statistical model in wireless communication that's used to explain how radio transmissions fade in a multipath environment. Multipath fading is a phenomenon caused by various pathways that wireless signals take as a result of diffraction, reflection and scattering. Variations in signal intensity and quality at the receiver may result from this fading. A variant of the mixture gamma distribution known as the Malaga distribution occurs when the mixture contains just one component or one Malaga distribution. In [1], a unified approach is introduced for representing the Electromagnetic Nano Communication system in an aqueous medium. This approach incorporates Mixture Gamma (MG) fading as a generalized fading distribution and a generalized Gaussian distribution (GGD) as a noise model. In [2], the deployment of NOMA in an FSO/RF system is explored to enhance spectrum efficiency. This is noteworthy as there are limited studies considering both NOMA and FSO/RF schemes simultaneously. In [3], the paper investigates the secrecy performance of a hybrid FSO-RF system within a NOMA framework. Analytical formulas for Signal-to-Noise Ratio (SOP) are derived, focusing on variable gain AF relaying, with FSO and RF links modeled as Gamma-Gamma fading and Nakagami-m distribution, respectively. In [4], the study introduces an analysis of dual hop uplink NOMA systems. It explores the transmission of amplified received signals from Rayleigh fading access links to the destination through an ultrahigh throughput directive interference-free FSO link susceptible to Gamma-Gamma (GG) fading with beam misalignment error, utilizing an AF relay. This work serves as a general analysis of dual-hop uplink NOMA systems and is a pioneering effort in implementing power-domain NOMA in mixed RF-FSO systems. In [5] employing NOMA to increase mixed RF/FSO harvesting duration and power allocation coefficients because low throughput is caused by short harvesting durations and short amounts of energy harvested. In [6] a non-orthogonal multiple access (NOMA) based mixed free space optical-radio frequency (FSO-RF) system with imprecise channel state information (CSI) and assess the secrecy performance in terms of secrecy outage probability (SOP). In [7] a two-user uplink NOMA system in which certain independent users may interact with each other during communication. Such interference may be brought on, for instance, by co-channel interference from adjacent users trying to reach other relays or destinations. In order to dynamically establish the NOMA users' detection order at the destination, author used dynamic order decoding. In [8] A novel Decode & Forward (DF)-based C-NOMA system is presented in the presence of two eavesdroppers. Furthermore, the analysis covers both half-duplex and full-duplex methods. In [9] A bit error rate (BER) and capacity analytical formulas for C-NOMA are presented, along with performance analysis results. In [10] The analysis of Bit Error Rate (BER) over Alpha-mu, Generalized-Gamma, and Rician fading channels between Source to Relay/Relay to Destination, or (S-R)/(R-D), is presented. In [11] The differential dual hop relaying system's BER analysis is presented along with

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a simulation of the GG fading channel. In [12] presents an investigation of the differential dual hop relaying system's performance across Alpha-mu fading channels with various modulation schemes and two-symbol non-coherent detection. In [13] proposed an MG distribution to model the SNR of a wireless channels.

Due to the linearly weighted sum of gamma distribution, mixture gamma distribution exhibits the various advantages. For instance, there are mathematically tractable formulations for the moment generating function (MGF) and CDF, which are necessary for wireless system analysis. Second, any small-scale fading channel can be approximated by this distribution, in addition to composite fading channels. Third, tweaking the parameters allows for excellent precision. All things considered, the MG model provides a consistent framework for analyzing the performance of any wireless systems across a range of fading channels. When modeling Free-Space Optical (FSO) communication lines, the Mixture Gamma distribution is in fact superior to the Malaga (M) distribution. Combining various Gamma distributions, each of which represents a distinct fading situation in the communication channel, results in the Mixture Gamma distribution. The Mixture Gamma model more accurately depicts the fluctuating atmospheric conditions and turbulence effects encountered by FSO links by utilizing a combination of the distributions. The Mixture Gamma distribution is capable of capturing the variety of fading behavior seen in actual FSO communication circumstances since it consists of several components. With additional intricacy, the model is able to describe the channel more realistically and more effectively, taking into account the dynamic nature of air turbulence. However, the manuscript is structured as follows: Section I provides the introduction along with a concise literature survey. Section II outlines the system and channel model. The Proposed Analytical Expression of Secrecy Outage Probability is detailed in Section III, while Section IV presents the results and various discussions. The paper concludes with Section V, summarizing the findings and offering conclusions.

II. System and Channel Model

As illustrated in Fig. 1, consider a NOMA system in which an Alice transmitter T connects directly with Bob receiver B and at the same time the Eavesdropper E receives the same parallel signal as receiver Bob B.

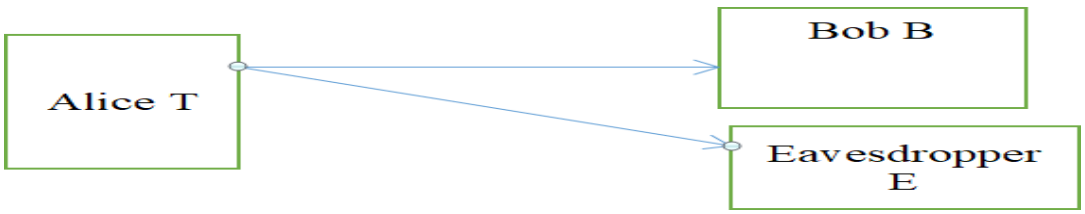


Fig. 1 System model for NOMA system

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The PDF of SNR for MG distribution can be shown as follows :

$$f_E(x) = \sum_{i=0}^{N} \alpha_{iE} \frac{x^{\beta_{iE}-1}}{\bar{x}} e^{-\frac{\varepsilon_{iE}.x}{\bar{x}}} \qquad (1)$$

$$F_B(\gamma_0) = \sum_{i=1}^{N} \alpha_{iB} \varepsilon_{iB}^{-\beta_{iB}} \gamma_0 \left(\beta_{iB}, \frac{\varepsilon_{iB}\gamma_0}{\gamma_0}\right) \qquad (2)$$

Where $\gamma_0 = R_s x + W_B,\ W_B = R_s - 1,\ R_s = 2^{Rt}$

Here α_{iE}, α_{iB}, β_{iE}, β_{iB}, $s_{iE.}$, s_{iB} all are the mixture gamma parameters. γ_0 is the SNR, (γ_0) is the CDF of SNR, R_s is the secrecy rate and R_t is the target rate.

Now

$$F_B(x) = \sum_{i=1}^{N} \alpha_{iB} \epsilon_{iB}^{-\beta_{iB}} x \left(\beta_{iB}, \frac{\epsilon_{iB}(R_{sB}x + R_{sB} - 1)}{(R_{sB}\bar{x} + R_{sB} - 1)}\right) \qquad (3)$$

Now using the formula of incomplete gamma function

$$\gamma(s,x) = \frac{1}{\Gamma s} \sum_{k=0}^{\infty} \frac{(-x)^k}{k!} \left(\frac{1}{s+k}\right) \qquad (4)$$

we find

$$F_B(x) = \sum_{i=1}^{N} \alpha_{iB} \epsilon_{iB}^{-\beta_{iB}} \frac{1}{\Gamma\beta_{iB}} \sum_{k=0}^{\infty} \frac{(-1)^k}{k!} \epsilon_{iB}^{k} \left(\frac{(R_{sB}x + R_{sB} - 1)}{(R_{sB}\bar{x} + R_{sB} - 1)}\right)^k \left(\frac{1}{\beta_{iB}+k}\right) \qquad (5)$$

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III. Proposed Analytical Expression of Secrecy Outage Probability

The Secrecy Outage Probability is :

$$P(x) = \int_0^{\infty} f_E(x) F_B(x) \qquad (6)$$

$$P(x) = \sum_{i=0}^{\infty} \sum_{i=1}^{N} \sum_{k=0}^{\infty} \frac{\alpha_{iE}\alpha_{iB}\epsilon_{iB}^{(-\beta_{iB}+k)}(-1)^k}{\Gamma\beta_{iB}\Gamma k\,(\beta_{iB}+k)\bar{x}(R_{sB}\bar{x}+R_{sB}-1)} \int_0^{\infty} x^{\beta_{iE}-1} e^{-\frac{\varepsilon_{iE}.x}{\bar{x}}} (R_{sB}x + R_{sB} - 1) \qquad (7)$$

Now let us solve the integration $\int_0^{\infty} x^{\beta_{iE}-1} e^{-\frac{\varepsilon_{iE}.x}{\bar{x}}} (R_{sB}x + R_{sB} - 1)$

Now using the formula $\int_0^{\infty} x^m e^{-x} \mathrm{dx} = m!$

$$\int_0^{\infty} x^{\beta_{iE}-1} e^{-\frac{\varepsilon_{iE}.x}{\bar{x}}} dx = (\beta_{iE})\,! \qquad (8)$$

$$\int_0^{\infty} x^{\beta_{iE}-1} e^{-\frac{\varepsilon_{iE}.x}{\bar{x}}} dx = (\beta_{iE} - 1)! \qquad (9)$$

$$\int_0^{\infty} x^{\beta_{iE}-1} e^{-\frac{\varepsilon_{iE}.x}{\bar{x}}} (R_{sB}x + R_{sB} - 1) = R_{sB}(\beta_{iE})\,! + R_{sB}(\beta_{iE} - 1)\,! - (\beta_{iE} - 1)\,! \qquad (10)$$

So

$$P(x) = \sum_{i=0}^{\infty} \sum_{i=1}^{N} \sum_{k=0}^{\infty} \frac{\alpha_{iE}\alpha_{iB}\epsilon_{iB}^{(-\beta_{iB}+k)}(-1)^k R_{sB}\,(\beta_{iE}!)}{\Gamma\beta_{iB}\Gamma k\,(\beta_{iB}+k)\bar{x}(R_{sB}\bar{x}+R_{sB}-1)} + \sum_{i=0}^{\infty} \sum_{i=1}^{N} \sum_{k=0}^{\infty} \frac{\alpha_{iE}\alpha_{iB}\epsilon_{iB}^{(-\beta_{iB}+k)}(-1)^k (R_{sB}-1)[(\beta_{iE}-1)]!}{\Gamma\beta_{iB}\Gamma k\,(\beta_{iB}+k)\bar{x}(R_{sB}\bar{x}+R_{sB}-1)}$$

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IV. Results and Discussion

The impact of several parameters of mixture gamma distribution on the system's performance is examined in this part using the analytical framework created in this research work.

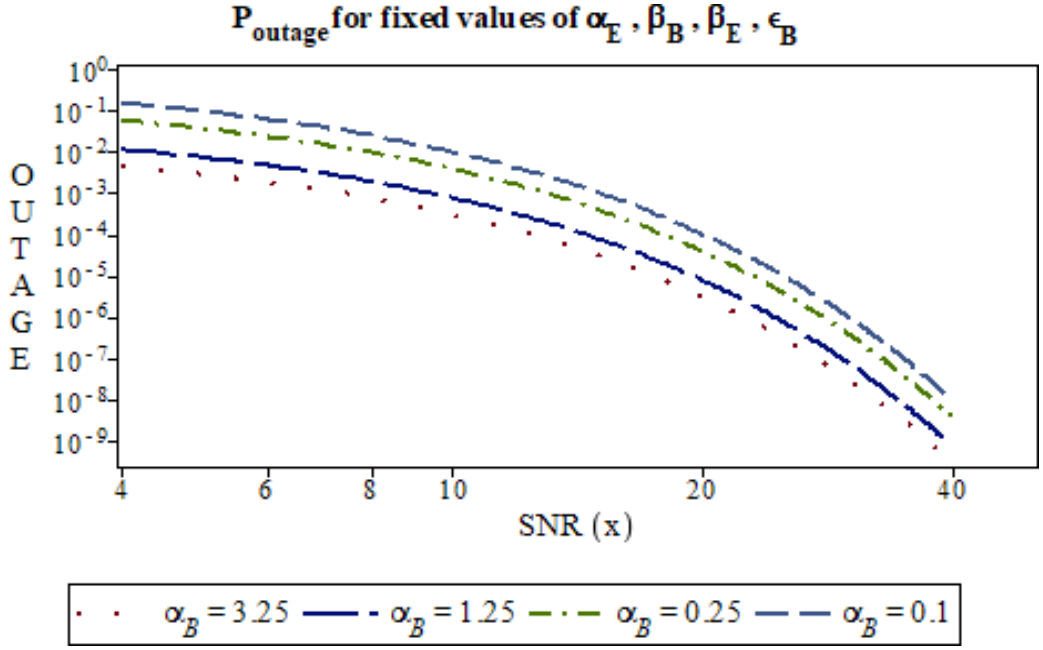


Fig.2 Secrecy Outage probability with mixture gamma parameter a_B

The analysis of secrecy outage probability with mixture gamma parameter a_B allocations is shown in Fig 2. In the study, the various curves between the secrecy outage probability and SNR are drawn on the fixed values of a_E, $\beta_B, \beta_E, \epsilon_B$ and at different values of a_B. It is assumed that a_E, β_B, β_E = {2.5, 2.5, 2.5},ϵ_B = 0.25 are the mixture gamma parameters allocated to transmit both signals on the same frequency and time. As shown in figure as the value of a_B decreases the secrecy outage probability will be increased.

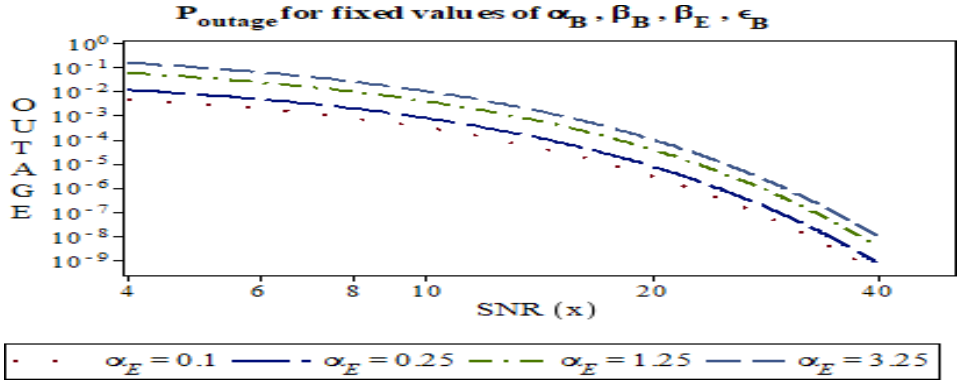


Fig.3 Secrecy Outage probability with mixture gamma parameter a_E

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The analysis of secrecy outage probability with mixture gamma parameter α_E allocations is shown in Fig 3. In the study, it is assumed that α_B, β_B, β_E = {2.5, 2.5, 2.5}, $c_B = 0.25$ are the mixture gamma parameters allocated to transmit both signals on the same frequency and time. As shown in figure for increase in the value of a_E the secrecy outage probability will be increased.

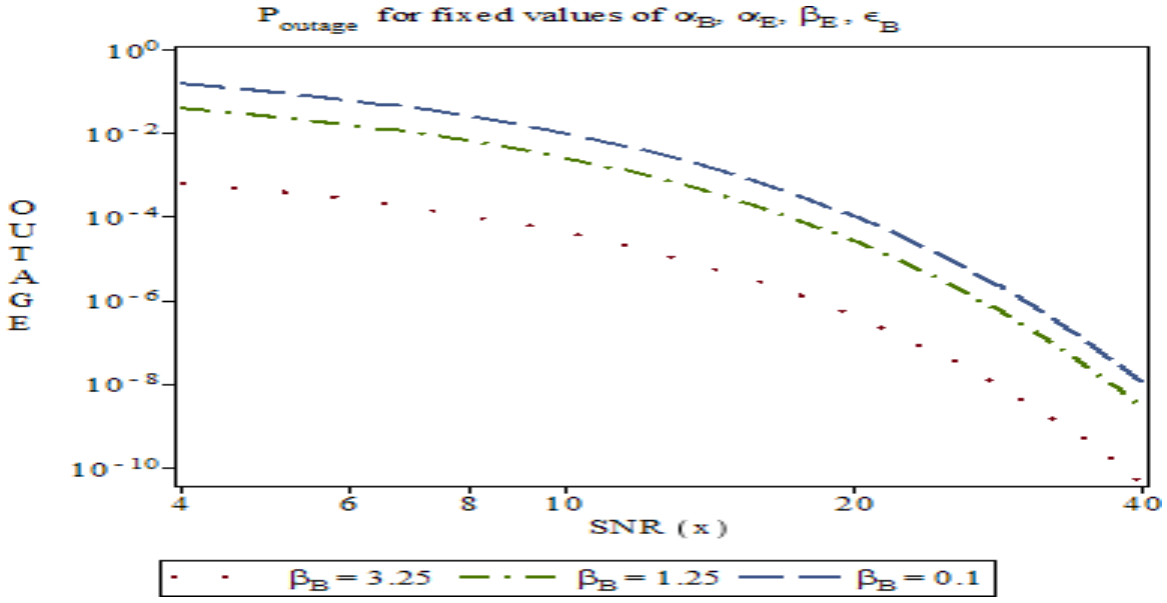


Fig.4 Secrecy Outage probability with mixture gamma parameter β_B

The analysis of secrecy outage probability with mixture gamma parameter β_B allocations is shown in Fig 4. In the study, it is assumed that α_B, α_E, β_E = {2.5, 2.5, 2.5}, $c_B = 0.25$ are the mixture gamma parameters allocated to transmit both signals on the same frequency and time. As shown in figure as the value of β_B decreases the secrecy outage probability will be increased.

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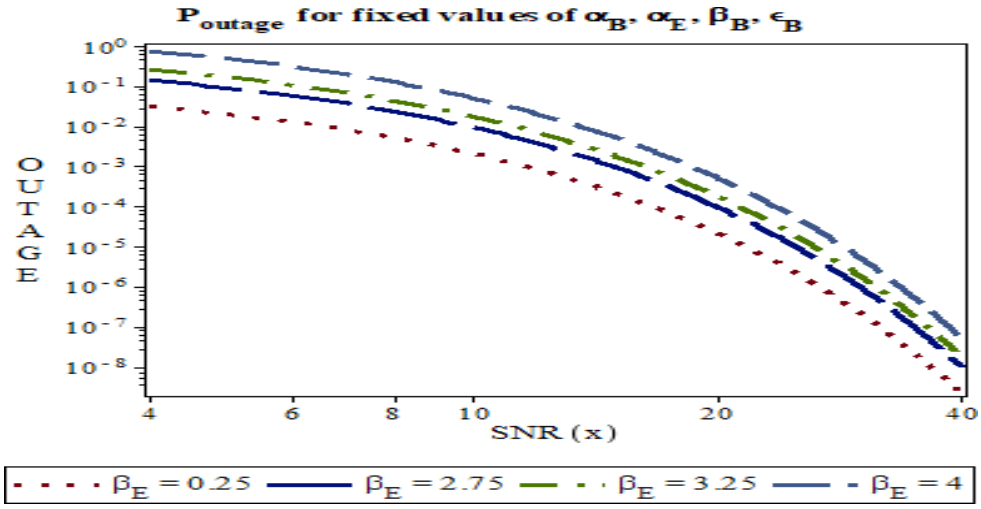


Fig.5 Secrecy Outage probability with mixture gamma parameter β_E

The analysis of secrecy outage probability with mixture gamma parameter β_E allocations is shown in Fig 5. In the study, it is assumed that α_B, α_E, β_B = {2.5, 2.5, 2.5}, $c_B = 0.25$ are the mixture gamma parameters allocated to transmit both signals on the same frequency and time. As shown in figure as the value of β_E increases the secrecy outage probability will be increased.

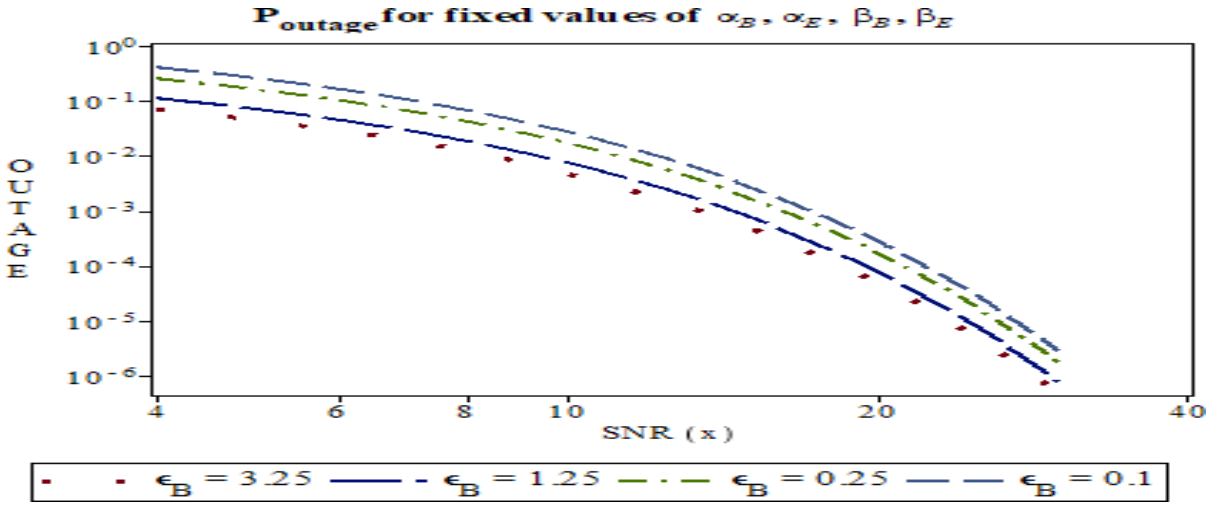


Fig.6 Secrecy Outage probability with mixture gamma parameter s_B

The analysis of secrecy outage probability with mixture gamma parameter c_B allocations is shown in Fig 6. In the study, it is assumed that α_B, α_E = *2.5,2.5+ and β_B, β_E = {2.5, 2.5}, are the mixture gamma parameters allocated to transmit both signals on the same frequency and time. As shown in figure as the value of s_B decreases the secrecy outage probability will be increased.

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V. Conclusion

Outage probability over MG fading distribution for NOMA system has been presented followed by presenting a new analytical expression. The proposed analytical expression has been quantified numerically with the help of numerical simulation. However, parameters used in analysis includes; shaping and severity of MG distribution. It has been observed that outage probability is affected by the various gamma parameters. Also, it has been depicted from numerical analysis that secrecy outage probability is increased by decreasing the values of gamma parameters for bob receiver and by increasing the values of gamma parameters for eavesdropper.

Finally, it has been observed that by controlling the value of gamma parameters for both bob receiver as well as for eavesdropper, we can control the secrecy outage probability of a NOMA system.

However, inclusion of mixed RF-FSO, Cooperative NOMA in the analysis can be immediate future scope. Also, other practical performance measures can be included in future aspect of the presented research.

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PROCEEDINGS OF 10TH INTERNATIONAL SYMPOSIUM ON FUSION OF SCIENCE AND TECHNOLOGY (ISFT-2024)
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ISFT ST - 06

VEGETABLE OILS AS SUSTAINABLE BIOBASED TRIBO FLUIDS

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Abstract

Biodegradable Lubricants are the need of the hour, since conventional total loss petroleum based lubricants contaminate groundwater, river & soil causing untold harm to environment, fish and wildlife also they are non-biodegradable. The vegetable oils are obtained from oilseeds (renewable resource), those could be thought as an alternate for lubrication. They have advantage of being biodegradable to an extent of 95% since obtained from renewable resource. A systematic study was undertaken to compare physicochemical properties of various vegetable oils in comparison to various ISO VG grade oils. It was observed that vegetable oils can be used as ISO VG grade 32 and 46 oils as Type HH hydraulic oils as per ASTM D 6158-18 standard.

Keywords

Total loss lubricants, renewable, biodegradable, physicochemical properties, vegetable oils, Type HH hydraulic oil, ASTM C 6158-18, viscosity index, flash point, pour point

Introduction

Lubricants are used in various activities like transportation, agricultural, mining and manufacturing. Starting from production, use and disposal, they leave a negative impact on health, safety and environment. The lubricants should be nontoxic through contact and inhalation during its production and use [**1**]. More than 50% of the lubes in the form of engine oil, industrial oil and hydraulic oils pollute the environment by the way of total loss applications such as leakage, undue spills and other routes. Fluids derived from mineral oil can pollute groundwater for up to 100 years, and even a trace amount of mineral oil (0.1%) shortens shrimps' lives by 20%. There are various methods for recycling spent lubricant oil, but each method has pros and

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cons as well as the issue of contamination to the environment. Because of this, there is a growing need for lubricants and fluids that are safe for the environment [**2,3**].

Mineral oils consist of linear hydrocarbons, cyclo alkyl hydrocarbons, aromatics and naphthenes while the vegetable oils are composed of triacylglycerols. Till 1850, the vegetable oils and fats were conventionally used as a source for energy and lubrication. After that the discovery of petroleum distillation by American scientist B. Silliman led to the formulation of fuels and lubricants derived from petroleum sources. Vegetable oils were outperformed by petroleum base stocks because of their accessibility, abundance, adaptability, and affordability. But the supply of basic minerals and fossil fuels is limited and could run out soon [**4-5**].

Vegetable oils and fats are derived from nature and extracted from renewable resources known as oilseeds. These oils are high molecular weight compounds having low volatility and outstanding rheological properties at elevated temperatures i.e. minimum change in viscosity with increase in temperature. Biodegradability and nontoxicity are the principle inherent characteristics exhibited by the vegetable oils, which are not found in mineral oils. The mild polarity of the vegetable oils offers better lubricity than petroleum base stocks, which are nonpolar in nature [**6-8**].

The combined efforts of reducing pollution and to find out a suitable alternative based on renewable resource were the two driving forces in exploring the possibility of using vegetable oils as lubricant base stock. The current study assessed the physicochemical characteristics of vegetable oils, including their acidity, iodine value, pour point, viscosity, viscosity index, and pour point in comparison with Type HH hydraulic oil basis ASTM D6158-18 specifications and examined the impact of additives that lower pour points and increase viscosity indices

Experimental details

Gift samples of rice bran, soybean, safflower, palmolein, and sunflower oils were received from M/s Godrej Industries Ltd. (Foods Division), Mumbai. Gift samples of groundnut and mustard oils were received from M/s Kamani Oils Pvt. Ltd. in Mumbai. Sesame, coconut, cottonseed, and olive oils were purchased from the neighborhood market. The viscosity index improver and pour point depressant additive samples were received as gift samples from M/s Sarbi Group of Companies, located in Mumbai.

Vegetable oils

Alkali refining of all the samples of vegetable oils was carried out for the removal of free fatty acids and the samples were tested for the various physicochemical properties.

Table 1. Physicochemical properties along with the test methods

Sr. No.	Name of the Test	Unit	Test No.
1	GLC analysis	(%) fatty acid	AOCS Ce 1-62, 4th Edition
2	Specific gravity	---	ASTM D-1298

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3	Acid value	mg KOH/gm	AOCS Cd 3d-63, 4th Edition
4	Saponification value	mg KOH/gm	AOCS Cd 3d-25, 4th Edition
5	Iodine value (Wij's)	gm I_2/100 gm	AOCS Cd 1-25, 4th Edition
6	Flash point (COC)	(^{0}C)	ASTM D-92
7	Kinematic viscosity	cSt	ASTM D-445
8	Viscosity index	---	ASTM D-2270
9	Pour point	^{0}C	ASTM D-97
10	Copper corrosion	---	ASTM D-130

Gas liquid chromatographic (GLC) analysis of vegetable oils

The free fatty acid quantity and composition of the fatty acids determine all of the physicochemical properties of the vegetable oils. Using the GLC approach, the fatty acid composition of vegetable oils was determined.

Preparation of methyl esters of vegetable oils [AOCS Official Method Ce 2-66]

1 gm of vegetable oil and 10 ml of 0.5 N methanolic sodium hydroxide were introduced in a 125ml flask equipped with a reflux condenser. The reaction mixture was refluxed on a steam bath for one hour. Ester layer was separated from glycerol in a separating funnel. Methyl esters were extracted using hexane and washed with warm distilled water, until the washings were neutral. Traces of moisture were removed on a steam bath at a reduced pressure of 10 mm Hg. The dried methyl esters were used to find out the fatty acid composition using gas liquid chromatography.

Gas liquid Chromatography [AOCS Official method Ce 1-62]

High temperature gas liquid chromatography was conducted on a Omega QC Gas Chromatograph, Netel Corporation, equipped with a stainless steel packed column of 2m length and inner diameter 1/8" with 10% diethylene glycol succinate (DEGS) as a stationery phase. Initially the column was maintained at 160^{0}C and then programmed @ 4^{0}C/min to 210^{0}C. Temperature of injector and flame ionization detector was kept at 260^{0}C respectively. 2µl sample of methyl ester was injected and nitrogen was used as a carrier gas with a flow of 30ml/ min through the column. Chromatograms and the area % reported were obtained by using peak. The Gas chromatograph column was standardized using methyl ester of samples of caprylic, capric, lauric, myrisic, palmitic, stearic, oleic, linoleic, linolenic, arachadic, behenic and lignoceric from Sigma Aldrich. The standardization was done using the same program as mentioned above to identify the exact retention time for that particular fatty acid.

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Physicochemical properties

All the refined oil samples were tested for specific gravity, acid value, saponification value, iodine value, flash point, viscosity at 40 and 100^0C, viscosity index, pour point and copper corrosion. At different concentration levels, the effects of a pour point depressant and viscosity index improver on vegetable oils were investigated. Every test for physicochemical properties was conducted in accordance with the procedures listed in Table 1. GLC of the methyl esters of vegetable oils was done as per *AOCS Official method Ce 1-62* and the fatty acid profile is as given below:

Table 2. Fatty acid profile of vegetable oils

Vegetable oils	Fatty acid chain length							
	C6	C8	C10	C12	C14	C16	C18	C18:1
Sunflower	---	---	---	---	---	5.50	4.70	19.50
Safflower	---	---	---	---	---	8.00	3.00	13
Soybean	---	---	---	---	---	11.00	4.00	22
Mustard	---	---	---	---	---	2.60	0.80	23.2
Groundnut	---	---	---	---	---	12.66	3.13	42.28
Cottonseed	---	---	---	---	0.61	24.59	2.61	18.52
Palmolein	---	---	---	---	1.1	38.60	4.30	43
Ricebran	---	---	---	---	---	16.40	1.80	42.3
Sesame	---	---	---	---	---	9.20	5.80	38.2
Coconut	0.30	0.26	6.77	53.79	20.00	8.12	2.43	6.78
Olive	---	---	---	---	---	11.83	3.44	59.63
	C18:2	C18:3	C20:0	C20:1	C22:0	C22:1	C24:0	Others
Sunflower	68.50	0.10	0.30	---	---	---	---	1.40
Safflower	75	1.00	---	---	---	---	---	---
Soybean	53.5	7.50	1.00	---	---	---	---	1.00
Mustard	8.9	10.40	0.70	8.10	---	43.10	---	2.20
Groundnut	36.19	0.91	1.20	---	2.26	---	1.37	---
Cottonseed	53.65	---	---	---	---	---	---	---
Palmolein	12.5	0.30	0.20	---	---	---	---	---
Ricebran	37.1	1.30	0.40	---	---	---	---	0.30
Sesame	45.1	0.60	0.50	0.60	---	---	---	---
Coconut	1.24	---	---	---	---	---	---	0.31
Olive	18.89	---	---	---	2.33	---	0.93	2.95

Results and Discussion

Results

Vegetable oils are high molecular weight tri esters of glycerol and fatty acids and based on fatty acid composition, the molecular weight ranges between 600 to 900 (Table 3).

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Table 3. Characteristics of the refined vegetable oils

Vegetable Oils	A. V. (mg KOH/ gm)	I. V. (gm I_2/ 100 gm)	S. V. (mg KOH/ gm)	Mol. Wt.	% Sat.	% Unsat.	% M Unsat.	% Di Unsat.	% Tri Unsat.
Sunflower	0.69	139.52	191.32	879.6	10.20	88.1	19.50	68.5	0.10
Safflower	0.75	143.27	194.52	865.2	11.00	89.00	13.00	75.00	1.00
Soybean	1.21	133.65	192.41	874.6	16.00	83.00	22.00	53.50	7.50
Mustard	1.10	104.37	171.86	979.2	04.10	93.60	74.30	8.90	10.40
Groundnut	1.17	98.85	195.67	860.1	18.36	79.38	42.28	36.19	0.91
Cottonseed	0.80	110.73	194.26	866.3	27.81	72.17	18.52	53.65	---
Palmolein	1.01	62.31	198.72	846.9	44.20	55.80	43.00	12.50	0.30
Ricebran	1.28	107.68	190.94	881.4	18.60	80.70	42.30	37.10	1.30
Sesame	0.71	114.53	189.16	889.7	15.5	84.5	38.80	45.10	0.60
Olive	1.13	08.34	187.39	898.1	18.53	78.52	59.63	18.89	---
Coconut	1.06	08.61	254.84	660.4	91.67	8.02	6.78	1.24	---

Fig.1. Plot of Flash point and Pour point (deg. C) vs. % Saturate content in Vegetable oil

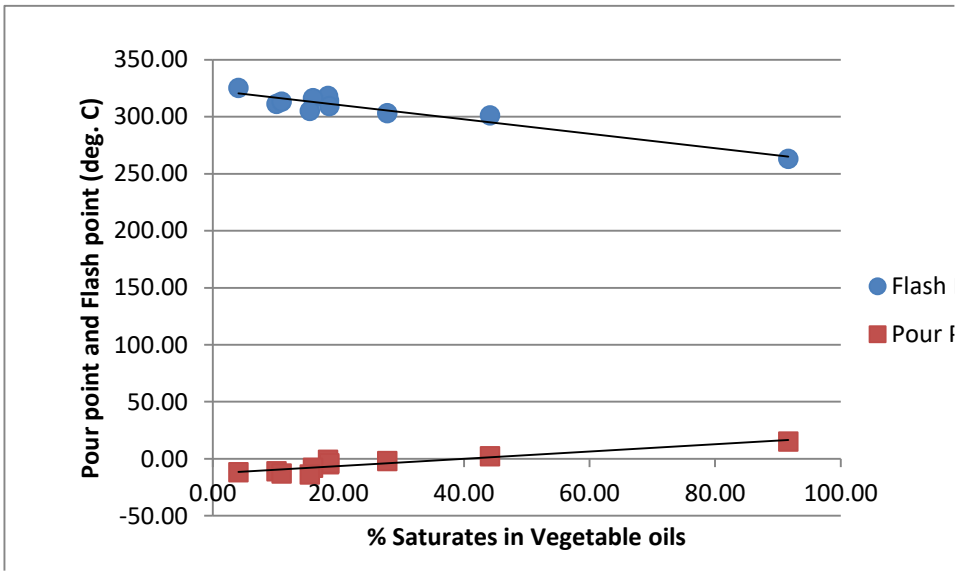
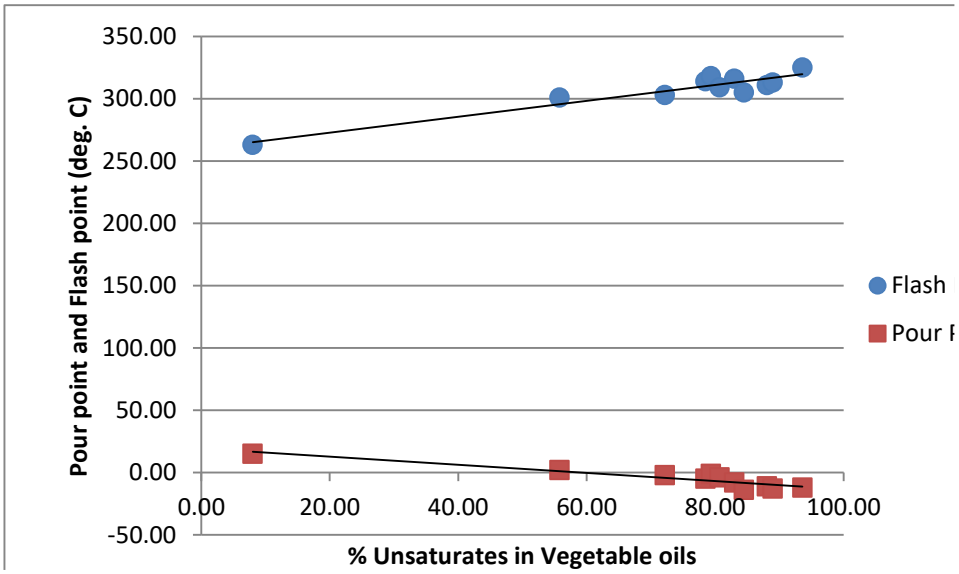


Fig. 2. Plot of Flash point and Pour point (deg. C) vs. % Unsaturate content in Vegetable oil

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Ester linkage is responsible for the polarity of the structure. The vegetable oils could be thought as candidate fluids due to the desired features like higher flash point, better oiliness (lubricity), viscosity and excellent viscosity-temperature characteristics (Table 4). As per Table 4 it is observed that majority of vegetable oils can be classified as ISO Viscosity Grades (VG) 32 and 46 basis there viscosity measured at 40C falling on between the given viscosity range at that particular temperature. The results of the physicochemical evaluation studies on various oils are discussed in sections 3.1 to 3.5 (Table 2-4).

Table 4. Physicochemical characteristics of the refined vegetable oils

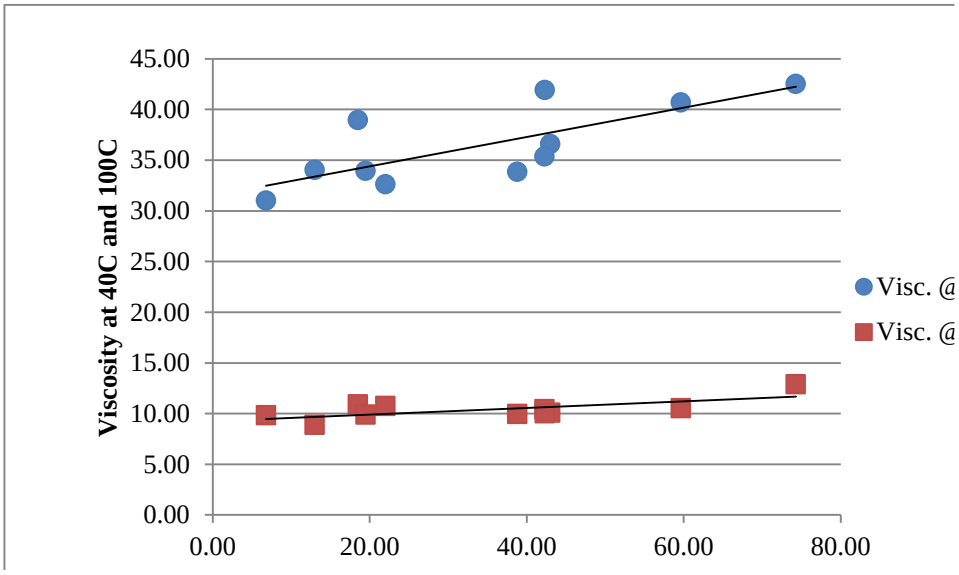
Vegetable Oils	Flash Point (^{0}C)	Flash point (deg. C) as per ASTM D6158-18	Pour Point (^{0}C)	Pour point as per ASTM D6158-18
Sunflower	311	185 min	–11	-6 max
Safflower	313	185 min	–13	-6 max
Soybean	316	185 min	–8	-6 max
Mustard	325	185 min	–12	-6 max
Groundnut	318	185 min	–1	-6 max
Cottonseed	303	185 min	–2	-6 max
Palmolein	301	185 min	+2	-6 max
Ricebran	309	185 min	–4	-6 max
Sesame	305	185 min	–14	-6 max
Olive	314	185 min	–5	-6 max
Coconut	263	185 min	+15	-6 max

Vegetable Oils	Viscosity at 40^{0}C	ISO VG Grade Oils Kinematic viscosity in cSt@40 C	Viscosity at 100^{0}C	Viscosity Index	Viscosity Index as per ASTM D6158-18	Copper Corrosion	Copper Corrosion as per ASTM D1658-18

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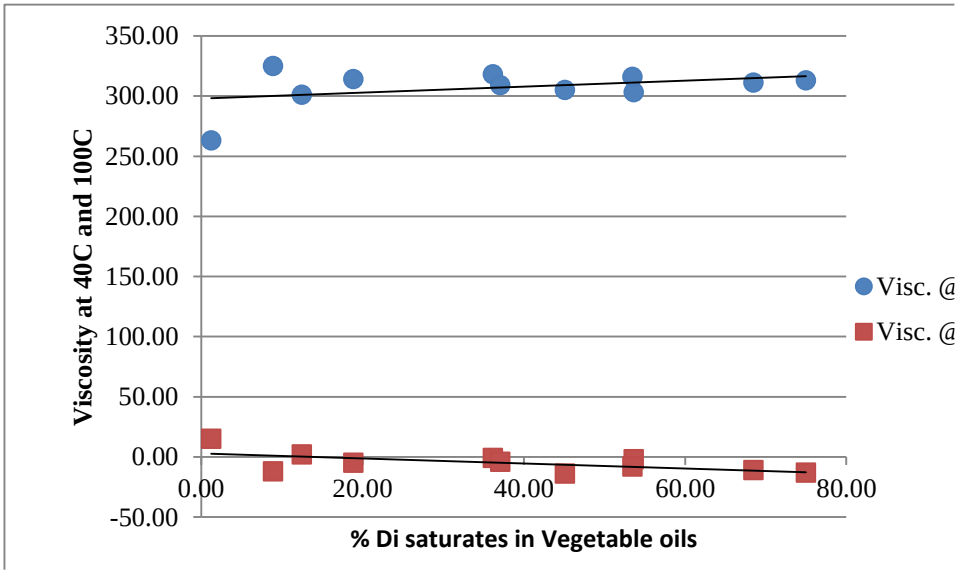
Sunflower	33.934	32 (28.8-35.2)	9.898	175.19	90 min	1 (a)	2 max
Safflower	34.030	32 (28.8-35.2)	8.882	170.46	90 min	1 (a)	2 max
Soybean	32.615	32 (28.8-35.2)	10.751	179.12	90 min	1 (a)	2 max
Mustard	42.512	46 (41.4-51.6)	12.895	171.37	90 min	1 (a)	2 max
Groundnut	35.358	32 (28.8-35.2)	10.417	174.57	90 min	1 (a)	2 max
Cottonseed	38.954	-	10.895	171.01	90 min	1 (a)	2 max
Palmolein	36.580	32 (28.8-35.2)	10.081	171.73	90 min	1 (a)	2 max
Ricebran	41.908	46 (41.4-51.6)	10.012	163.10	90 min	1 (a)	2 max
Sesame	33.850	32 (28.8-35.2)	9.967	175.53	90 min	1 (a)	2 max
Olive	40.692	46 (41.4-51.6)	10.530	167.40	90 min	1 (a)	2 max
Coconut	31.02	32 (28.8-35.2)	9.840	179.49	90 min	1 (a)	2 max

Fig. 3. Viscosity @ 40C and 100C vs. % Mono saturate content in Vegetable oil



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Fig. 4. Plot of Viscosity at 40C and 100C vs. % Disaturate content in Vegetable oil



The data in Tables 3 and 4 have undergone statistical regression analysis, and an attempt has been made to deduce conclusions from the R squared and P values found in Tables 5 and 6. Results that are statistically significant are shown by P values less than 0.05, and the strength of the correlation between the independent and dependent variable is indicated by R squared values.

Table 5. Statistical analysis of the results obtained for Flash and Pour point

Variable (Y)	Flash Point			Pour Point		
Variable (X)	R squared	P value	Results are Statistically	R squared	P value	Results are Statistically
C16	0.036	0.57	Not Significant	0.207	0.15	Not Significant
C18	0.121	0.29	Not Significant	0.099	0.345	Not Significant
C18:1	0.0069	0.8	Not Significant	0.037	0.57	Not Significant
C18:2	0.211	0.15	Not Significant	0.002	0.89	Not Significant
C18:3	0.67	0.002	Significant	0.697	0.0013	Significant
Sat.	0.908	0.0000565	Significant	0.85	0.00005	Significant
Unsat	0.894	0.0000108	Significant	0.86	0.00003	Significant
M Unsat	0.325	0.066	Not Significant	0.088	0.37	Not Significant
Di Unsat	0.141	0.254	Not Significant	0.367	0.048	Significant

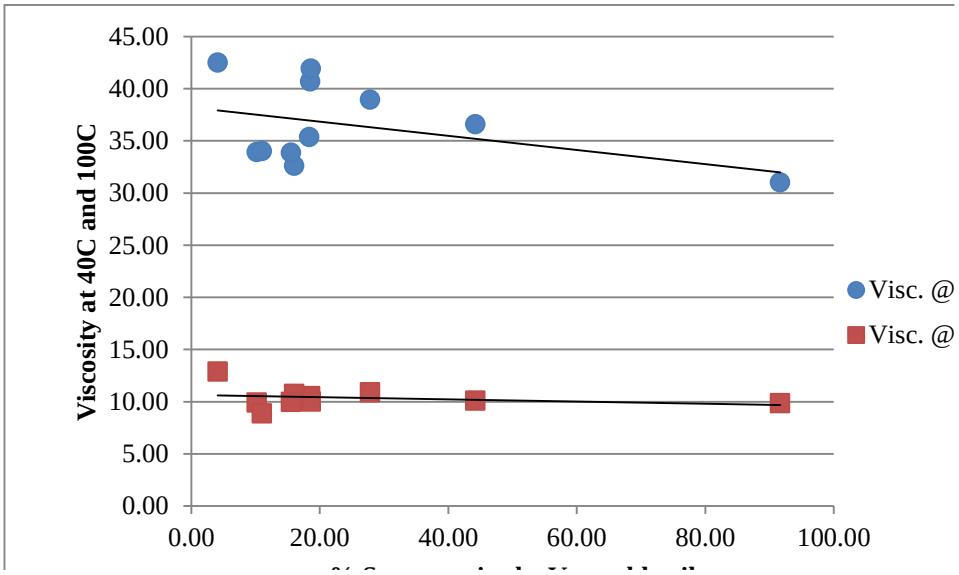
Table 6. Statistical analysis of the results obtained for Viscosity @40C and @100C

Variable (Y)	Viscosity @ 40C			Viscosity @ 100C		
Variable (X)	R squared	P value	Results are Statistically	R squared	P value	Results are Statistically
C16	0.001	0.9	Not Significant	0.0344	0.581	Not Significant
C18	0.213	0.15	Not Significant	0.009	0.77	Not Significant

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C18:1	0.169	0.21	Not Significant	0.155	0.23	Not Significant
C18:2	0.73	0	Significant	0.44	0.025	Significant
C18:3	0.158	0.22	Not Significant	0.017	0.7	Not Significant
Variable (Y)		Viscosity @ 40C			Viscosity @ 100C	
Variable (X)	R squared	P value	Results	R squared	P value	Results
Sat.	0.176	0.198	Not Significant	0.067	0.44	Not Significant
Unsat	0.166	0.212	Not Significant	0.057	0.47	Not Significant
M Unsat	0.577	0.0066	Significant	0.45	0.023	Significant
Di Unsat	0.077	0.4	Not Significant	0.19	0.176	Not Significant

Fig. 5. Plot of % saturates in vegetable oil vs. Viscosity at 40C and 100C



Discussion

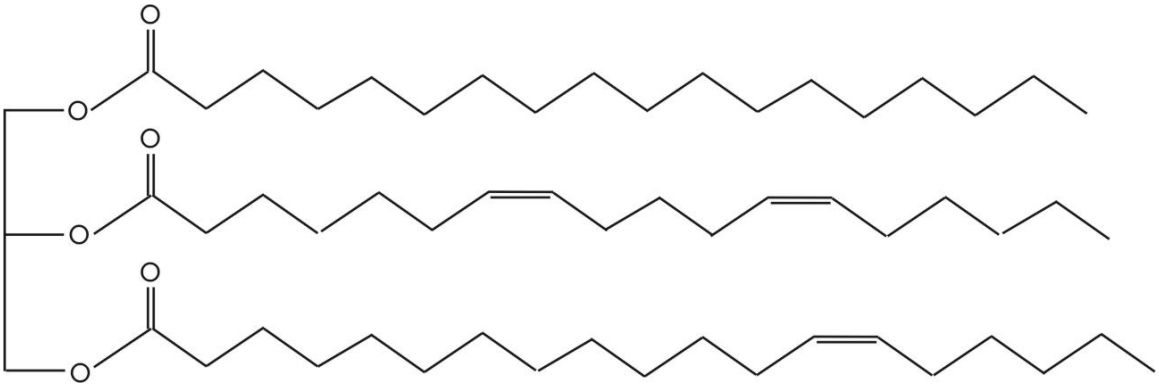
Physicochemical evaluation of vegetable oils (Table 2-4)

All the vegetable oils have common basic structure, where three hydroxyl groups of the glycerin backbone are esterified with the three molecules of fatty acids, which are same or different, saturated or unsaturated. The majority carbon chain length of fatty acids is roughly 18, and the structure of all triglycerides typically consists of six oxygen atoms and roughly sixty carbon atoms. The necessary range of properties for the pour point, oxidation stability, and additive/(s) compatibility are absent from native vegetable oils. High viscosity index, improved boundary lubrication, low volatility, high flash point, nontoxicity, and biodegradability are the desired qualities of vegetable oils. common vegetable oils biodegrade up to 80% into carbon dioxide and

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water in 28 days under conventional test settings (e.g., OCED 301D test technique), compared to 25% or less for common petroleum-based lubricants. Lower oxidative stability is caused by the presence of linoleic/linolenic acid, while poorer cold flow behavior is caused by long-chain saturated fatty acids. [**9**].

Fig. 6. Triglyceride molecule having three different fatty acids



Effect of free fatty acid content on the flash point of vegetable oils (Table 2-4)

Flash point of a lubricant is the higher operating temperature beyond which a lubricant cannot be used for a desired application. Therefore, higher flash point is preferred for all kinds of lubricants. The vegetable oils are composed of a mixture of triglycerides and free fatty acids. Flash point of any fluid is a function of molecular weight of the constituents of fluid. i.e. It depends on the percentage low volatile components. The triglycerides are less volatile as compared to free fatty acids. Vapour pressure of fatty acid is higher than that of triglyceride at a given temperature. Therefore, flash point is lower for a high free fatty acid content and vice versa. Flash point of the refined oils was found to be in a range of 263^0C to 325^0C, highest being for mustard due to presence of erucic acid, which was highest molecular weight fatty acid (Mol. Wt. 338) and the lowest being for coconut oil due to the presence of lauric acid, a low molecular weight fatty acid (Mol. Wt. 200). The majority of refined oils had flash points between 3000 and 3150 degrees Celsius. This resulted from the vegetable oils' high content of saturated and unsaturated C18 fatty acids. It is common for fatty acids to corrode at high temperatures. For this reason, it is advised to use refined oils for lubrication at all working temperatures (oils with very low FFA, preferably < 0.1 mg of KOH).

Effect of viscosity index improver on viscosity and viscosity index of vegetable oils (Table 4)

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The viscosity of all the vegetable oils (at 40^0C) obtained ranged between 34 cSt to 42 cSt because of predominance of C_{18} fatty acids. This was reflected in its saponification value that ranged between 185 to 195 mg of KOH (Table 3-4). Viscosity index improvers are high molecular weight polymeric compounds having coiled structure. At 40^0C, the viscosity remained fairly constant due to less compatibility of viscosity index improver with triglycerides at ambient temperature. Significant change in viscosity was observed at 100^0C (Table 4) and slight increase in viscosity occurred at 100^0C after blending the vegetable oils with viscosity index improver. This increase in viscosity was due to uncoiling of the viscosity index improver additive at elevated temperatures that partly compensated for the change in viscosity. Viscosity index is rate of change of viscosity w.r.t temperature. All the oils were found to have outstanding viscosity temperature characteristics. The viscosity index ranged between 162-180 and only a small change in the viscosity index was observed after blending of additive at a level of 5%.

Effect of free fatty acid content, iodine value and pour point depressant on the pour point of vegetable oils (Table 2-4)

Any vegetable oil's pour point is determined by the proportion of unsaturated (oleic acid, linoleic acid, and linolenic acid) and saturated (lauric acid, myristic acid, palmitic acid, stearic acid, etc.) fatty acids. Higher pour points are caused by the presence of saturated fatty acids, whereas lower pour points, as shown by iodine values, are attributed to unsaturated fatty acids. Saturated fatty acids beyond C_{10} were solid at room temperature. Presence of unsaturation was responsible for higher iodine value and low pour point. Major unsaturated fatty acids present in the vegetable oils were oleic acid (monounsaturated fatty acid), linoleic acid (diunsaturated fatty acid) and linolenic acid (triunsaturated fatty acid). Melting point of oleic acid is 16^0C, linoleic acid is -5^0C and that of linolenic acid -11^0C [**10**]. However, this unsaturation adversely affects the oxidative stability of the oil, which is necessary for the shelf life at high temperatures. The natural antioxidants present in the oils were lost during the subsequent refining stages, leading to reduction in oxidative stability. This was compensated by the addition of antioxidant package. [**11-13**]. Iodine value of coconut oil was lowest at 8.61 due to the presence of saturated fatty acids to the extent of 91.67% (Table 2-4). The undesirable effect of saturation reflected in highest pour point, which was 15^0C (Table 4). The iodine value of mustard oil and safflower oil was 104.37 and 143.27 respectively. Mustard oil had 93.60% of unsaturated fatty acids and a pour point of -12^0C, whereas safflower oil had 89% of unsaturated fatty acids and a pour point of -13^0C. This difference was due to the presence of erucic acid in mustard oil and linoleic acid in safflower oil. It was also due to similar percentage of saturated and mono, di & tri unsaturated fatty acids present in the oils. Mustard oil had highest percentage (10.40%) of linolenic acid, which is lowest melting fatty acid. Linolenic acid & erucic acid synergistically lowered the pour point of mustard oil. Free fatty acids (FFA) present in the oils had a great impact on the pour point. FFA is a high melting fraction, which was responsible for higher pour point and crystallized out first at lower temperature. These crystals acted as nucleating sites for further

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agglomeration and interfered with the flow properties of the fluid. Such crystals bound the entire liquid that stopped the movement of the liquid molecules in all the directions. Pour point of the oils was improved with the addition of pour point depressant. The pour point depressant co-crystallized with the high melting fraction i.e. free fatty acids and avoided the growth of the crystals. Overall the pour point was effectively lowered by 6^0C to 7^0C with the usage of additive at a level of 0.1-0.5%.

Inference of Statistical Analysis (Table 5 and Table 6)

With a R squared value of 0.9 and 0.85, respectively, Table 5, Fig. 1 and Fig. 2 demonstrates strong correlation between the lubricants' pour point and flash point with the amount of saturated and unsaturated fatty acids. With a R squared value of 0.9 and a p value less than 0.05, it is further deduced that an increase in saturated content there is decrease in the flash point and pour point further increases with increase in saturate content. For example coconut oil has a largest total saturate content of 91.6 7% but its flash point is 263 C while Mustard oil with a total saturate content of 4.1% has a flash point of 325 C. This inverse relation in saturate content and the flash point can be explained by the fact that higher flash point is actually strongly correlated to higher molecular weight. Average molecular of coconut oil is 660.4 while that of Mustard oil is 979.2. Mustard oil's higher molecular weight is attributed to presence of higher amount of C22 carbon chain length fatty acids of about 43 % while lower molecular weight of Coconut is attributed to higher presence of C12 carbon chain length fatty acid of about 53 %. Since the P-value is less than 0.05, then the findings are considered statistically significant. With a R squared value of 0.85 and a p value less than 0.05, the pour point decreases much more when the unsaturated content rises as compared to reduction in saturated content.

Table 6, Fig. 3 and Fig. 4 demonstrates that the presence of disaturates and monosaturates has a greater effect on the lubricant's viscosity than that of saturates, with R squared values of 0.73 and 0.57 at 40 °C while there is no effect on viscosity at 100C which is proved by lower R squared values of 0.44 and 0.45 at 100 °C, respectively. Fig. 3 shows that there is increase in viscosity with increase in Mono unsaturated content with Mustard oil with the highest mono unsaturated content of 74.3 showing viscosity @ 40C of 42.51 cSt. Ideally more unsaturation should result in lesser viscosity but here the increase in viscosity should be attributed to the higher molecular weight because of 43% of C22 carbon chain length fatty acid content of Mustard oil. This logic is backed up by Coconut oil's lowest viscosity of 31.02 cSt at 40C with highest saturate content of 91.6% as shown in Fig. 5 indicating that it is not the of amount of saturates but the molecular weight of fatty acid chain length has more impact on viscosity.

Conclusions

Fast depletion of crude oil reservoirs across the globe and demand & supply for petroleum products are driving factors for the viable alternatives based on renewable resources. Hence

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Vegetable oils were studied for their physicochemical properties as per ASTM D6158-18 [**14**] against the specifications for Type HH Hydraulic oil (ISO VG 32 and 46) are non-inhibited refined mineral oils for hydraulic systems that do not have specific requirements of oxidation stability, rust protection, or anti-wear properties. Type HH oils are usually intended for total loss systems or very light-duty equipment. It was found that all the physicochemical properties such as flash point, Viscosity index, Copper corrosion were met. Pour point specifications of Type HH Hydraulic oil were met for Sunflower, Safflower, Soybean, Mustard and Sesame oil. While Groundnut, Cottonseed, Palmolein and Ricebran oil will require addition of pour point depressants for lowering there pour points further. In order to make them suitable to substitute Type HL, HM hydraulic oil the study of tribological properties has to be done after addition of Rust inhibitors, Antioxidants and Antiwear and Extreme pressure additives. Viscosity at 40C and Flash point of the oil is more impacted by molecular weight of the oil than its content of saturated and un-saturated fatty acids.

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Leveraging the Metaverse for Sustainable Solutions in the Reduction of Environmental Impact, with a Focus on Virtual Offices, Classrooms, and Nature Experiences

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Abstract

This research looks at how the Metaverse could help make our environment more sustainable by using virtual offices, virtual schools and experiencing nature in a more immersive way. The Metaverse can help cut down carbon footprints and make people more aware of the environment by giving choices for commuting. It also examines the creation of Real-life feeling virtual nature experiences to lower real travel's harm on the environment and raise awareness for it. Overall, this research looks closely at the current situation and suggests ideas for future studies by combining a comprehensive survey with an analysis of existing metaverse platforms.

Keywords

Metaverse, Virtual Reality, Augmented Reality, Environmental Sustainability, Virtual Education, Sustainable Development.

Introduction

Background

The Metaverse, a virtual world that's quickly changing and linked together is growing fast. It's like going inside into a big digital universe. Next big change in our everyday lives. The more we use it in our lives, the need to use its powerful ability to face and fix problems grows. Global concerns becomes more apparent, one of these problems is the damage to nature caused by common ways like traveling or going to work. This paper is designed to investigate the mutual relationship between the Metaverse and environmental sustainability, looking at how this digital world could be a strong base in the worldwide effort to have harmony with nature.

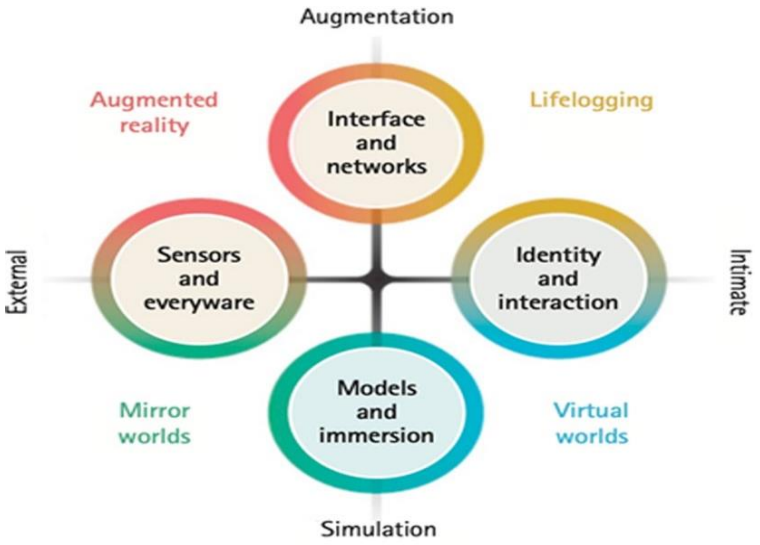
The Metaverse and its Potential

The term "metaverse" is not something new. Neal Stephenson first talked about it in his book called "Snow Crash" from 1992 [1]. The Metaverse is a digital immersive experience that replicates or

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substitutes the real environment, it is a platform for spatial computing. A metaverse can be wholly or partially virtual; for example, a totally virtual world, such as a virtual reality (VR) system, or a partially virtual world, such as the usage of augmented reality (AR) in real-world circumstances [2][25]. Mark Zuckerberg officially announced the Metaverse project in October 2021, making it a popular topic.

Fig 1 According to the Metaverse Roadmap Summit [3], this is a diagram showing the four categories of Metaverse.



Its immersive environments and interactive interactions provide unimagined opportunities in a variety of industries, including sustainability. This paper delves into the Metaverse's tremendous potential as a powerful catalyst for environmental development. According to Fig 1, Metaverse technology is divided into four categories: AR (Augmented Reality), Lifelogging, Mirror Worlds and Virtual Worlds. The two parts that separate the four groups are Augmentation versus Simulation and External versus Intimate [24]. Augmentation technology links digital information to the real world we see. This adds a new way of seeing to places that were already there [21].

A Green Revolution in the Digital Realm

Climate change, environmental deterioration, and resource depletion are all serious threats to our world. Traditional approaches have limitations, but the Metaverse emerges as a one-of-a-kind instrument for dealing with these difficulties. The Metaverse has the potential to transform how we live, study, and connect with the environment by enabling virtual workspaces, immersive environmental education, remote ecotourism experiences, and so on [23]. The idea of the

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Metaverse is not new in education because some experts and researchers have already looked at its effects on how we learn. For example, a research paper released in 2006 by Kemp and Livingstone examined how to merge Metaverse with a virtual world called "Second Life" to improve learning [4][22]. Metaverse opens up new avenues for education, allowing for the creation of very dynamic and fascinating lessons, simulations, and other forms of learning. Furthermore, the use of secure, decentralized technology such as blockchain ensures the secrecy and security of user data and allows for the formation of virtual economies that can be used to recompense users for their participation and learning [26]. Various research studies suggest that governments should make efforts to use green energy, develop convenient rapid public transport, conserve and scientifically plan urban water bodies to address the issues faced by megacities meet, and increase the urban sustainability [5][6][7].

The Environmental Impact of Traditional Practices

While the Metaverse promises a digital revolution for sustainability, understanding the environmental consequences of present activities is crucial. Traditional behaviours, such as daily commuting and considerable travel, contribute significantly to pollution, carbon emissions, resource depletion, and environmental deterioration. Daily commuting causes traffic congestion, air pollution, and stress on public resources, especially in densely populated urban regions. Similarly, frequent travel for work, school, or leisure increases carbon footprints and puts additional strain on natural ecosystems. Pollution-related diseases account for around 16% of all fatalities worldwide each year, which is more than smoking, AIDS, tuberculosis, and malaria combined [8]. As cities grow in size, so does the environmental impact of traditional behaviours. Traffic emissions not only harm air quality but also highlight the critical need for long-term solutions.

Objectives

Setting out on a task to discover the synergistic relationship between the Metaverse and environmental sustainability, the primary objectives of this research are twofold:
To assess the Metaverse's potential for fostering environmental sustainability, and to explore and analyse existing projects and innovations in the Metaverse, with a focus on virtual offices, classrooms, and nature experiences, as key components in reducing environmental impact.

In order to achieve these objectives, the research examines the below RQs:

RQ1. What role can the Metaverse play in promoting environmental sustainability?
RQ2. What are the potential environmental benefits of Metaverse virtual workplaces and schools, taking into account existing projects and innovations?
RQ3. How might immersive virtual nature experiences help to reduce the environmental effect

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of physical travel?

Developing hypotheses enables a systematic study to examine specific assumptions drawn from research questions:

H1: The incorporation of virtual offices and schools into the Metaverse will result in significant carbon footprint reductions when compared to traditional physical venues.
H2: Immersive virtual nature experiences in the Metaverse will improve environmental consciousness and, as a result, reduce the environmental impact of actual travel.

Materials and Methods

Materials

The hardware and software utilized in this research included VR headsets, for immersive experiences. Computers, laptops, and smartphones, as well as other standard computing devices, were critical tools for accessing and engaging with the Metaverse. Furthermore, the [EngageVR, Breakroom Virtual Classroom [Fig 2], Spartial, Zepeto, Zigbang] Metaverse platforms and applications functioned as key interfaces for virtual experiences. To inform the research and methodology, a comprehensive review of relevant literature, research papers, and documentation was conducted, with key materials including [9] [28][30].

Fig 2 Breakroom Virtual Classroom - A snapshot showcasing the immersive virtual learning environment where participants engaged in dynamic virtual classrooms, emphasizing innovative features designed to enhance the learning experience within the Metaverse



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Methods:

Analysis of Existing Metaverse Platforms

Virtual reality is often viewed as the other end of things from mixed reality to augmented reality, it is also defined as an internet-based 3D area that several users can access at the same time and engage in by creating an avatar that expresses the user's personality [14][27]. Bringing Metaverse into various aspects of our lives has allowed us to work remotely in Metaverse workstations. As a result, an increasing number of businesses are creating Metaverse workstations for mobile business, and mobile operators around the world are using Metaverse platforms for engagement, networking, and collaboration such as Gadar, Teamflow, Meta, or the organization they work for [10]. Zigbang, the major business in the Korean PropTech industry, It is one among the companies that has developed its own Metaverse platform for remote work. Zigbang launched Metapolis in 2021, it is a Metaverse platform used as a remote collaboration Fig 3. Moving

Fig 3 Zigbang's Metaverse Work Office



around avatars to chat instantaneously, employees find metaverse offices significantly better for telework when we think about communication. No physical distance, just a virtual workspace boosts the efficiency, and yes, megacities do offer lucrative jobs, but they come with their own baggage. Air pollution, the sky touching cost of living, and ever-present traffic jams are but a few of their unsustainable aspects.[15]. If big city folks can work from home, thanks to tech like metaverse, they may contemplate relocating to areas with lower living expenses and higher environmental quality.

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ENGAGE is a business-oriented spatial computing platform. This tool enables distant training, teamwork, functions, and promotions. It lets our customers interact directly with staff, clients, and vendors in virtual places and digital twins. It is vitally designed for educational organizations and professionals. When compared to traditional education, studies suggests that the use of VR technology in teaching/learning experiences has favourable impacts, increasing student engagement and amplifying learning outcomes [18][19][26].

Fig 4 An event in Engage VR with a class in progress and multiple people present with their avatars

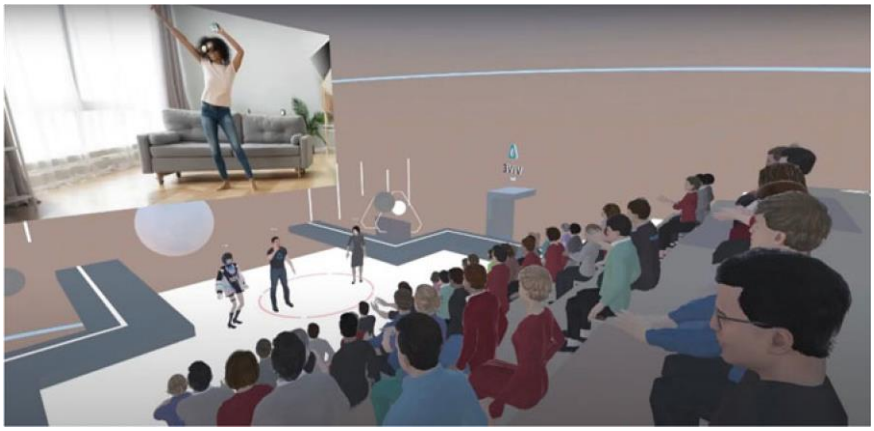


Fig 4 depicts a virtual class in progress during an immersive educational event within Engage VR. The presence of multiple participants, each represented by their avatars, emphasizes the dynamic and interactive aspect of metaverse-based classrooms. It's adequate for hosting conferences, education, simulated training, and events, and it also includes numerous VR learning and developing an innovative digital Learning environment with metaverse features.

Another metaverse platform that was explored was Zepto. Naver Z's Zepeto, an AR avatar service, it serves as a representative metaverse platform in Korea. Zepeto, which debuted in 2018, generates a "3D avatar" to converse with other users by combining facial recognition, augmented reality, and 3D technologies [20][26][29].

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Fig 5 Zepeto class 2 map. From the Snow Corporation [19]



Multiple maps can be used to carry numerous activities like playing games or doing instruction-based role plays. Think about a teacher who sets up a room, invites the students, and communicates with them using voice or messaging on the map of the classroom

Fig 5 [20].

Survey Methodology

Participant Engagement:
Approximately 50 Students and several faculty members from Aalim Muhammed Salegh College of Engineering, Chennai, India actively participated in immersive experiences within selected Metaverse platforms that was analysed.

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Survey Design

Following the immersive encounters within the chosen Metaverse platforms, a meticulously built survey utilizing Google Forms was used to delve into participants' nuanced experiences with virtual offices, classrooms, and outdoor activities. The survey structure used a mixed-method approach, carefully mixing open-ended and closed-ended questions to obtain a thorough knowledge of the participants' perspectives.

Survey Section	Key Focus Areas
Virtual Offices	Efficiency, Productivity, Impact
Virtual Classrooms	Education Effectiveness, Engagement, Sustainability
Nature Experiences	Enjoyment, Ecological Awareness, Preferences

The above **Error! Reference source not found.** provides an overview of the key focus areas w ithin each survey section, directing the subsequent discussion on user experiences and perceptions in virtual offices, classrooms, and nature simulations. In our study we used closed ended questions, with Likert scales and numerical ratings to gather data on attitudes and experiences. In contrast ended questions were designed to allow participants to share their in-depth observations capturing the full richness of their experiences. Before distributing the survey to all participants, we conducted a pilot test with a group to identify any difficulties and improve the surveys clarity and relevance. Our goal was to create a survey design that would collect both quantitative information and insightful qualitative narratives providing a strong foundation, for future research.

Data Analysis

We conducted a data analysis to gain an understanding of how participants experienced the Metaverse. We used statistics to analyse the survey responses, from the participants. In the Table 1 the data such, as mean values, standard deviations and frequency distributions will gives us a detailed view of how users perceive offices, classes and nature experiences.

Table 1 Descriptive Statistics for Virtual Offices Efficiency, Virtual Classrooms Engagement, and Nature Experiences Enjoyment

Aspect	Mean	Standard Deviation	Frequency Distribution (1-5)

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Virtual Offices Efficiency	4.2	0.8	1: 2% | 2: 5% | 3: 15% | 4: 40% | 5: 38%
Virtual Classrooms Engagement	4.5	0.6	1: 1% | 2: 2% | 3: 8% | 4: 25% | 5: 64%
Nature Experiences Enjoyment	4.7	0.5	1: 0% | 2: 1% | 3: 5% | 4: 20% | 5: 74%

After reviewing the information provided in Table 1 there are a few observations that can be made. These statistics offer insights, into how the Metaverse has the potential to improve effectiveness and involvement, across fields. You can find the results discussed in detail in the Results and Discussion section.

Hypothesis Testing

H1: The incorporation of virtual offices and schools into the Metaverse will result in significant carbon footprint reductions when compared to traditional physical venues.

To examine Hypothesis 1, we conducted a t test to compare the carbon footprints (\mu AVN and \mu BVN) of individuals involved in offices (AVN) and traditional physical locations (BVN) respectively. The t statistic was computed using the formula;

$$t = (\bar{X}AVN - \bar{X}BVN) / (s / \sqrt{n})$$

where $\bar{X}$ represents the sample mean, s is the sample standard deviation, and n is the sample size.

H2: Immersive virtual nature experiences in the Metaverse will improve environmental consciousness and, as a result, reduce the environmental impact of actual travel.

For Hypothesis 2, we- utilized a change examination te-st (ANOVA). This looked at the nature-awareness ratings among various immersive nature experience (IVNE) groups. We also conducted extra checks using the Tukey Honestly Significant Difference (HSD) strategy. This checked for particular variations among groups.

The results for both H1 and H2 are presented in the Results and Discussion section.

Experimental Setup

Virtual Platforms and Technologies

Communication Tools

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Easy-to-use communication tools were launched for better people involvement in the Metaverse. These were key for folks to take part and work together in virtual workplaces and class discussions. Important perks, like video chats, quick typing chats, and helping work together platforms, encouraged talking and sharing.

Virtual Reality (VR) Headsets and Platforms

Virtual reality (VR) he-adsets were used, but not extensively. Key devices from top brands played a role in boosting the depth of virtual interactions. The aim was to see how augmented virtual landscapes could positively impact user involvement and interaction. Studying various Metaverse platforms was important during the research. The ones discussed in theMaterials and Methods were chosen for their singular traits and abilities. This allowed for a rich and full investigation of virtual offices, classrooms, and nature experiences in the Metaverse.

Survey Implementation

We used a survey as a key tool in our study. We asked folks who attended different Metaverse events to fill it out. The survey had questions about stuff like if the event was productive, educational, engaging, fun, and eco-friendly. We also asked about what they liked generally. We crafted this survey to get thoughtful answers. These answers will help to inform the ensuing analysis and discussions.

Results and Discussion

Survey Results

This research provides important information on how people interacted with the Metaverse's digital spaces like offices, classrooms, and outdoors. **Error! Reference source not found.** in the M ethods part details the primary topics each part of the survey touches. The questionnaire aimed to get insights on user vie-ws and encounters with Metaverse in different scenarios, from online workspaces and digital classes to virtual outdoor adventures. In the Methods section, Table 1 displays the in-depth stats for aspects like productivity in Virtual Offices, involvement in Virtual Classrooms, and fun factor of Nature Experiences.

Virtual Offices

We looked at how well virtual offices worked, it yielded a mean score of 4.2, which means most people liked them. The people we asked said they found virtual offices easy to use and practical. They liked tools that helped them work together online. Scores didn't vary much; everyone was pretty much agreed. The frequency distribution shows that 78% of people gave a score of 4 or 5.

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So, most people liked the-se online places to work. This is a good sign. If we can use more virtual offices, we can help to save the environment by cutting down on traditional travel.

Virtual Classrooms

In virtual classrooms, we got the mean score of 4.5, showing high involvement. A standard deviation of 0.6 means good experiences were common. 89% rated their virtual classroom experience 4 or 5, showing a trend towards success with web-based learning. This backs up the idea that the Metaverse could change education. It makes learning lively, fun, and cuts out travel. It also helps the environment.

When we check other features, we see users consistently happy in virtual offices, classrooms, and nature simulations. The Metaverse gets high scores. It's widely accepted and could provide lasting solutions.

Nature Experiences

The mean score of 4.7 for virtual nature sessions suggest folks really enjoyed them. The tiny standard deviation of 0.5 shows these virtual trips get stable, enjoyable reactions. Almost 94% of the folks found these digital trips truly exciting, giving them 4 or 5 points. This positive reaction to these virtual trips underscores their ability to make us more aware of our environment and lessen the damage of actual travel. These digital substitutes can help encourage green habits by offering fun and eco-friendly off-time choices.

Hypothesis Testing Results

H1: The incorporation of virtual offices and schools into the Metaverse will result in significant carbon footprint reductions when compared to traditional physical venues.

A crucial difference ($t(19) = 11.11$, $p<0.001$) was seen when comparing carbon footprints between virtual offices (AVN) and traditional physical venues (BVN) utilizing a t-test. This result backs up Hypothesis 1, proving that the Metaverse emits fewer carbon footprints than traditional physical venues. This conclusion aligns with the Metaverse's promise to increase environmental sustainability by providing virtual options to physical areas. The significant decrease in carbon footprints underlines the Metaverse's potential role in shaping a greener and more sustainable future.

H2: Immersive virtual nature experiences in the Metaverse will improve environmental consciousness and, as a result, reduce the environmental impact of actual travel.

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We used ANOVA and did analysis, to study environmental awareness. It's based on different immersive nature experiences (IVNE). There were different groups. We found something interesting, it revealed a significant effect (F (2,57) = 8.63, p 0.001). A group called VR Nature Walk showed more care for the environment. They outperformed other groups, including VR Nature Exploration and Control. These results came from further tests using the Tukey HSD method. These findings supported Hypothesis 2. It suggests that virtual nature time in the Metaverse ups environmental consciousness. That's more than traditional methods can do.

Discussion

It appears that both virtual work and school in the Metaverse not only boost turnout and involvement, but also aid in saving the planet. Users marked high satisfaction with their digital offices, revealing an enduring alternative to the regular job. Likewise, online classrooms showed active participation, suggesting a game changing role in learning and less environment harm compared to regular travel. Positive reactions to virtual outdoor activities highlight the Metaverse's role in raising nature awareness through green entertainment choices and fostering ecofriendly decisions.

Limitations and Future Directions

The research provides helpful data, but some issues need attention. The number of participants and their backgrounds might limit its applicability. More diverse groups should be included in upcoming studies, and long-lasting impacts need assessment. Also, this research focused on specific Metaverse platforms. Future studies could explore a wider assortment of platforms and tools.

Conclusions

In conclusion, this research looks into how the Metaverse can change the game in aiding environment-friendly practices. The research focused on Metaverse's virtual workplaces, learning spaces, and nature adventures. The response was pretty good, people loved spending time in these digital areas, showing that the Metaverse could offer alternatives to old ways. This could help make our future greener.

Based on what people said, virtual offices and classrooms in the Metaverse are not just effective and fun, they could also help us greatly reduce our carbon footprints. And that is in comparison with actual offices and classrooms. Furthermore, the immersive virtual trips in nature proved to be fun and enlightening for environmental understanding. This aligns with the Metaverse's

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pledge to switch up education, job, and pastime patterns with the environment in mind. Educators and companies looking at using Metaverse technology will find this study useful.

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AMBIENT INTELLIGENCE IN HEALTHCARE

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Abstract

Artificial Intelligence (AI) is becoming an important aspect of every individual's life. With machines handling human jobs to the introduction of robots, any milestone can be achieved with the help of this technology. This paper presents how AI is overcoming the shortcomings of human power and utilizing this technology in the field of healthcare. Assorted methods depicting Machine Learning (ML) have also been described. The comparison of supervised, unsupervised and reinforcement learning techniques has also been discussed. The integration of Artificial Intelligence (AI) into healthcare heralds a new era of ambient intelligence, revolutionizing the way medical services are delivered and accessed. This paper delves into the multifaceted role of AI in healthcare, exploring its ability to transcend human limitations and enhance patient outcomes. Through a comprehensive examination of Machine Learning (ML) techniques, including supervised, unsupervised, and reinforcement learning, this paper elucidates how ambient intelligence permeates every facet of the healthcare ecosystem. By leveraging AI models and visual aids such as flowcharts and roadmaps, the authors elucidate the myriad applications of AI in medicine and healthcare. The paper also underscores the importance of recognizing and addressing the inherent limitations of AI technology in healthcare. The authors also make an effort to describe a model and various applications of AI in the field of medicine and healthcare with the help of flowchart and roadmap. The paper also discusses the limitations of artificial intelligence and the future of AI in the healthcare sector.

Keywords

Machine Learning, Artificial Intelligence, Deep Learning, Natural language processing, Neural Networks.

Introduction

Artificial Intelligence (AI) all set to make human lives smart in every sphere of their lives. AI can lead to advancement in healthcare workers and patient communications while maintaining

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confidentiality as well [1]. AI is mainly categorized into two main domains, which include Machine Learning (ML) techniques and Natural Language Processing (NLP) methods. ML techniques analyze structured figures. There are a wide range of applications of ML in the field of healthcare and medicine. The potential of ML, AI and other statistical tools include diagnostic accuracy, reliably predicting prognosis, improved treatments, and better operational efficiency of healthcare systems. NLP methods make use of information extraction from unstructured data including the notes from clinics, the medical history of the patient and the patient's behavioral aspects. These ML techniques aim to turn the texts into high level machine structured readable data. The emergence of ambient intelligence in healthcare represents a paradigm shift in the delivery of medical services, wherein AI systems seamlessly integrate into the healthcare environment to enhance patient care and clinical decision-making. This introduction sets the stage for a comprehensive exploration of AI's role in transforming healthcare delivery. By harnessing the power of AI-driven ambient intelligence, healthcare providers can optimize workflows, streamline processes, and deliver personalized care experiences. Through the lens of Machine Learning (ML), encompassing supervised, unsupervised, and reinforcement learning techniques, this paper elucidates how ambient intelligence empowers healthcare professionals to make data-driven decisions and improve patient outcomes. The same data is further analyzed by ML techniques [2]. This paper presents how AI is overcoming the shortcomings of human power and utilizing this technology in the field of healthcare.

Literature Survey

One of the key factors for investing in AI as a solution in the healthcare sector is its specific and positive economic impact [3]. AI refers to the intelligence of machines. AI refers to the ways machines work like humans, how they learn, apply and create new applications [1, 2]. Another way to define AI is designing and creating ‘‘intelligent agents”. An AI agent or device can grasp and acknowledge its environment and take necessary actions so as to attain maximum probability of its goals. Finding an output to a given complication and responding as a human neural system, that is, learning and analyzing, is known as ML [4]. AI is particularly concerned with algorithms [5]. We can impersonate the behavior of the human brain which is a cognate network of neurons, with weighted servicing and transmitting routes within the neurons. With multiple changes in the surrounding stimuli, a neuron changes its state according to the varying inputs [6] and hence resulting in the generation of outputs responding to the environmental stimuli, similar to the human neural system. The different types of learning performed by Neural Networks are discussed below:

Supervised learning

The work involved in supervised learning involves inferring a function with labeled datasets. If the output of the given task is a continuous value then the task is considered as regression and if the output is discrete then the task is referred to as classification. Some real life examples are classifying lung diseases, recognizing body organs through image recognition. Techniques using both labeled and unlabeled dataset are called Semi-Supervised learning methods.

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Unsupervised learning

Learning from test data that is not labeled or unlabeled data is the task involved in unsupervised learning. Identifying common features in the data is done. Real life applications of unsupervised learning includes dimensionality reduction feature selection, anomaly detection with clustering, predicting heart diseases and hepatitis disease prediction using principal component analysis (PCA).

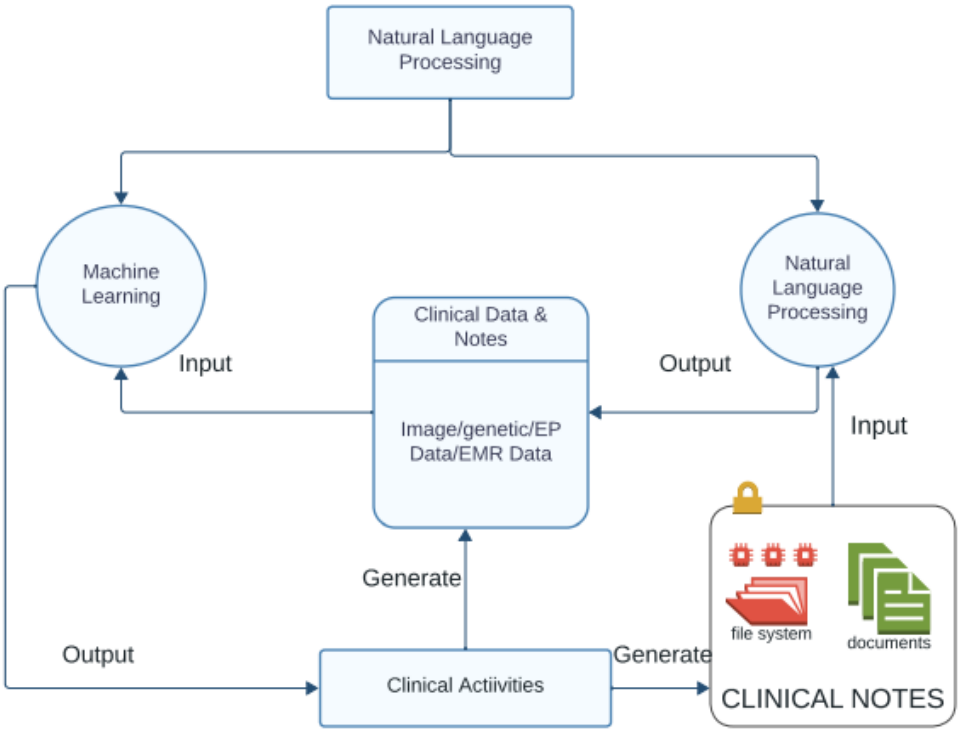
Reinforced learning

Here the model acts and reacts according to the environment and is given rewards or penalties on completing the task accurately or unable to accomplish the task correctly [7]. The applications of Reinforced learning include disease prognosis of context-aware symptoms. Mobile health or m-health is monitoring the health using mobile phones and health monitoring devices. Z. Faizal Khan and Sultan Refa Alotaibi explored the development of techniques using AI and big data as a source for handling m-health data effectively [8]. Continued growth in future is anticipated because of the benefits that AI can offer to the healthcare industry [9-11]. This paper reviews applications, challenges, issues, and the future of AI in the field of healthcare.

The major role can be played by AI in the field of healthcare sector in achieving goals such as personal, predictive, preventative, and participatory, and in these directions. We can very well predict that there will be a drastic growth in the development of AI in the healthcare field. Different machine learning models are discussed below along with the flowchart and roadmap of AI by using ML and NLP. An introduction to ML models, types of ML algorithms and the prediction the model is analyzed. Various applications of AI in the field of healthcare and the issues and challenges related to AI in healthcare are included. Discussion about the future of AI and finally, conclusions are summarized further.

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Fig 1. Roadmap of Implementation of AI for various clinical activities



Machine learning models

The flow chart represented in Figure 1 indicates the road map starting from clinical activities and data, by the means of NLP and ML data analysis and solving clinical activities. The usage and implementation of the powerful AI tools should be kept up to date by clinical problems and testing data frequently.

Machine learning consists of a set of methods, which allow a machine to react and grasp useful data and learn innovative techniques interacting with humankind. The fact that power of a machine is in the hands of humans cannot be ignored. Whatever we teach the machine, it learns and gives output the way it was taught. Such knowledge can help a machine to work more efficiently and effectively. Medical imaging is rapidly emerging as one of the most used ML techniques. With this fast improving world, DL has become an important aspect of ML technique that is being utilized. Through the means of DL we can solve many complex problems and even learn these complicated patterns. Deep learning is very vital for the field of medical imaging analysis as it has taken many years of expertise of data for appropriate feature determination.

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ML can be broadly classified into three major genres on the basis of the concerned input:

Unsupervised learning

This learning is known for a very essential attribute which is feature extraction. Algorithms used in unsupervised learning include clustering and dimensionality reduction. Clustering helps in identifying the structure and substructure in the provided input data.

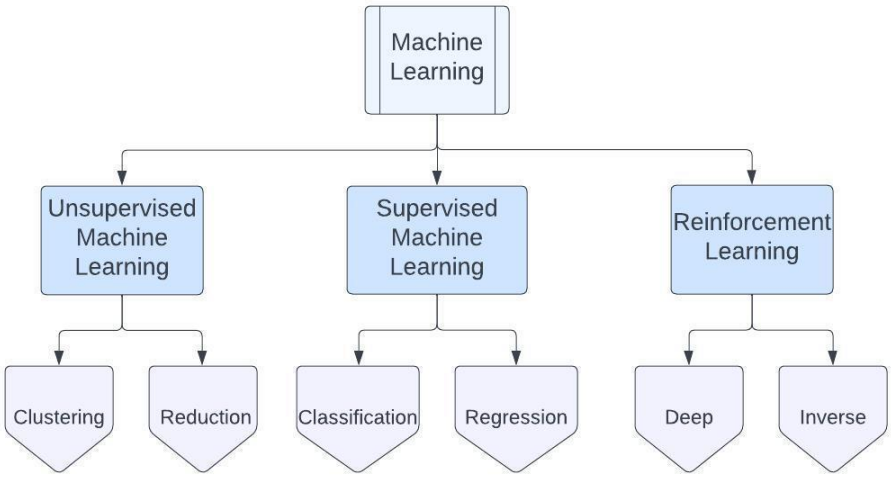
Supervised learning

This learning is suitable for predicting models by the means of building relationships between the output of interest and the parent inputs. Supervised learning works with labels and on prior knowledge of the given data. Algorithms used in supervised learning include classification and regression. The Support Vector Machine (SVM) also plays an important role in this type of machine learning.

Reinforcement learning

Algorithms used in reinforcement learning include deep reinforcement learning and inverse reinforcement learning. Reinforcement learning is totally different from unsupervised and supervised learning as its algorithm learns from interacting with the environment unlike learning from past data and experiences. It is mostly applicable in situations where a series of decisions have to be made.

Fig.2. Learning Algorithms used for ML



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Model Mapping

A model is a file used to identify patterns by recognizing them. It is also a map gathering inputs from "X" to the outputs or predictions "Y", mathematically a function. It is basically presumed that a real time data generating unknown function (F(X)) exists. For choosing the data for any model to grasp the information, the output and the process for working it should be discussed in an orderly manner. In addition to that, the time required for the model and the space it requires should also be taken into consideration while predicting and selecting a model. The dataset which is used by the model to learn is defined as the training dataset. We often keep a portion of the training dataset aside for tuning the hyper parameters [10]. Data kept aside is called a validation dataset. The provided variable weights to a parameter and their combinations are called hyper parameters. Let the number of patients be n and we represent each patient by a d-dimensional feature vector lying in some space X supposing. Assuming label Y is representing the outcome or the actual situation of the patient. We are testing a single binary label for a patient and learning a map from the vector X to Y. We can use a ML algorithm like Stochastic Gradient Descent to predict the data [11].

F(X) represents the ratio of the degree of the output model to the degree of its correct depiction (Figure 3). The validation dataset helps to check whether the options of the given framework of our model is accurate or inaccurate. The given model has to be tested from the given training or validation data to analyze the classification performance and predicting on a holdout test dataset. The test dataset should be minimally close to the data model and can be applied for usage [12-14].

The end goal of our model and the ML algorithm decide the choice of the parameters required. The method used for modeling and the biases inherent in the data determine the degree of generalization of a model during their functioning. Some important aspects affecting the performance of the model would be brief rendition of data asset collection and processing, process of sub-selecting the validation dataset and the prevailing attributes used in predicting the data.

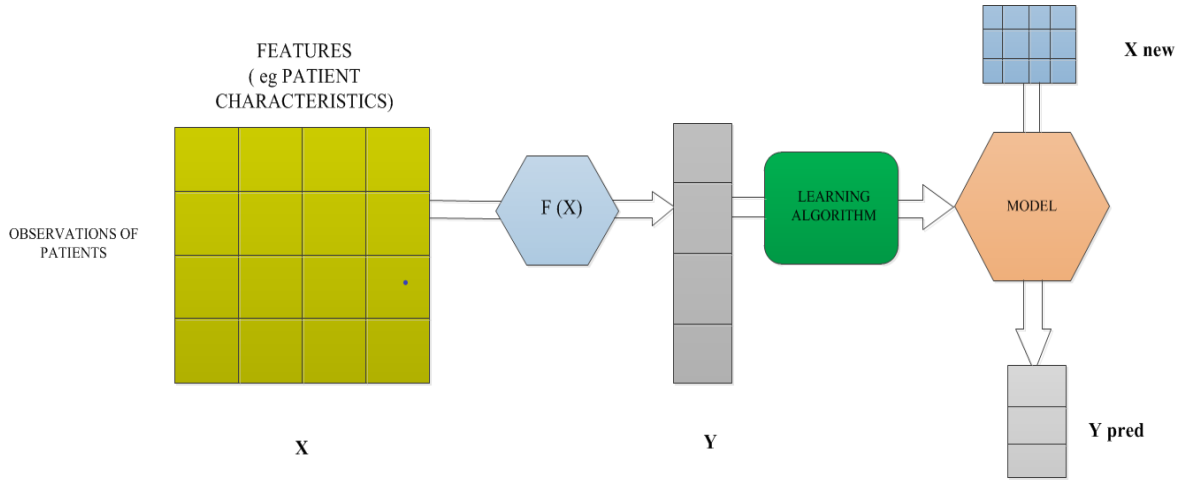
Data mapping is used to collect and enhance a model with the features of another model. Model segregation models are differentiated in a single list together making the maintenance and bug hunting easier to perform [15].

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Fig. 3. Model mapping depicted from input (X) to output (Y) over true underlying process, F(X).



A description of the analyses and measurements related to answering the central research questions. The interpretation of the results, considering their significance, and putting them into a wider context through comparison to previously published research

Applications of AI in the Field of Healthcare

AI finds various applications in clinical care; some of them are discussed next.

Medical imaging
Medical scans are collected and stored in a temporary memory. Then this data is used as the training dataset and further tested reducing the cost and being time efficient. AI based technology has shown recognized results in identifying conditions like pneumonia, various kinds of cancers and even eye diseases [20].

Echocardiography: AI can be used to scan the presence of cardiac electrograms with the help of heartbeat pattern recognition and investigate other heart related diseases.

Monitoring the neurological state: Various AI techniques are being created to analyze speech

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patterns to anticipate deranged circumstances and check any traits of neural imbalance including Parkinson's disease.

Surgery: AI driven mechanized gadgets are being applied to perform valued functions surgeries such as the keyhole surgery. Closing the open wounds by suing them and binding those knots also uses AI robotic tools.

Stroke: The developments of these AI techniques are used for three major sectors of care: beforehand prediction and analysis, curing the patient, and predicting the output along with prognosis evaluation.

Drug discovery: AI is also being used to detect patterns in vast and complex datasets more productively and efficiently. AI also has applications in aid drug discovery.

The robot scientist or The EVE is a special robot designed by researchers to have an efficient and faster method for drug discovery. It is one of the most economical drug discovery methods [16-18].

Challenges Faced by AI in the Healthcare Sector

A vital obstacle in implementing Artificial Intelligence in the field of medicine and healthcare is the deficiency of clinical datasets and training datasets on a wider range. Mainly the collection of labeled data requires the assistance and expert annotation of doctors and experts, thus making this process costly and inefficient over time [16]. Though, we can majorly apply AI tools to conditions with limited amounts of labeled training data in this precinct.

There are still many queries without answers about the comfort of a patient with the sharing of personal health data digitally. Data transparency and leakage are another major disadvantage to look into when considering AI systems. Cyber insecurity and hackers may also be a threat to this technology. Robots and various other AI systems might lack human qualities like compassion or love. Many complex verdicts in clinical practices are not correctly replicated by the AI systems including contextual skills and the realization to predict public intimation. A dispute arises on the fact that AI techniques match human knowledge and can human tactics be taught.

Reliability and Safety: These are the two main complications concerning AI, in the zone of controlling the equipment, delivering treatment and most importantly making the decisions as a human. Errors can be made by AI and the implications could make things worse for the patients and the healthcare organizations [17]

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Transparency and Accountability: Another concern with AI is the difficulty to understand the logic behind the output a machine is going to present. Some AI would be capable of possessing a secret, but others might be very hard to understand by humans. ML techniques may be exceptionally blurred due to their way of continuous learning of rules and constant checking of parameters.

Data Privacy: Many patients have troubles with their data privacy and information seeking. It is a very important concern for human beings. They want their privacy to be held *accountable*. Also, the needs of the patients are to be satisfied by the healthcare authority which is generally neglected by machines and robots [16-19].

The Future of AI

The advanced development of any country in the field of healthcare as well as other sectors depends on the machine using technology of AI and ML, power the nation has.AI techniques help reduce the workload of humans and also are more efficient and accurate. In the near future we will soon see human activities being done by artificially intelligent robots. Scientists are still in progress to reach the horizon of discovering the field of artificial intelligence and machine learning [15,17,20-22].

Many researchers believe that by the fore-coming years AI and ML based robots and machine bots would govern all the sectors especially, the healthcare sector.

Artificial intelligence has broad applications in military operations, medical assistance, robotic dogs, space robots etc. The scope of AI and ML will only excel in the upcoming future. It's how mankind makes use of it and grasps hold of this technology.

Conclusion

In conclusion, this paper has provided a comprehensive examination of the advantages and limitations of AI and ML in the healthcare domain. Through the utilization of roadmaps, comparison charts, and flowcharts, various attributes of AI and ML have been elucidated, offering a clear understanding of their capabilities and potential impact. The discussion encompassed a range of techniques including NN , NLP , and ML, highlighting their respective roles and contributions to advancing healthcare.

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The paper delved into numerous applications where AI and ML have demonstrated significant efficacy, ranging from diagnostic assistance to personalized treatment recommendations. However, amidst these advancements, it is crucial to acknowledge and address the challenges faced by AI and ML in healthcare, such as data privacy concerns, algorithm biases, and regulatory hurdles.

The role of AI and ML in healthcare is poised for substantial growth, with promising prospects for improving patient outcomes, enhancing operational efficiency, and revolutionizing healthcare delivery. As evidenced by the discussed techniques and methodologies, AI and ML offer invaluable tools that hold immense potential for benefiting humanity. By navigating through the challenges and leveraging the opportunities presented, the integration of AI and ML into healthcare systems can lead to transformative advancements, ultimately contributing to a healthier and more prosperous future for all.

The authors findings underscore the pivotal role of Artificial Intelligence and Machine Learning in shaping the future of healthcare, affirming their significance as indispensable allies in the pursuit of better health outcomes and improved quality of life [22-24].

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Comprehensive Survey for Cell-Free Massive MIMO under 6G Communication System

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Abstract

Excellent reliability, low latency, excellent spectrum efficiency, and tremendous energy efficiency are all required by the digitalized intelligent network. Massive multiple-input multiple-output (mMIMO) systems that are cell-free (CF) are among the most important technological developments to satisfy these unprecedented demands. Standard massive MIMO is a component of the 5G network; under 6G, it is transformed into cell-free or distributed massive MIMO, with some significant modifications that will be covered in the paper that is being presented. In CF-MMIMO, a enormous amount of distributed access points that are directly connected to the network controller serve a very huge number of users.

Keywords

MIMO, massive MIMO , 5G mobile communication, signal processing, 6G communication, cell-free massive MIMO

1 Introduction

The study and development of forward-thinking wireless communication, also known as 6G, are positioned to give even more astounding performance across every domain as 5G pursues its rapid deployment as well as integration into the everyday life of individuals. Globally available, 5G is reaching new heights in terms of industry, hospital, school, office, and home collaboration. Multiple-input multiple-output is defined as MIMO. MIMO is essentially a wireless network that enables the simultaneous transmission and reception of several data signals over a single radio channel, albeit involving different technologies. Typically, two or four antennas are used in standard MIMO networks. One of the most revolutionary technologies of the last few decades is MIMO. [1, 2]. Typically MIMO is categories in two forms-

- **Single User MIMO (SU-MIMO)**- The Base station (BS) serves single user at a time in case of SU-MIMO [3].
- **Multi User MIMO (MU-MIMO)**- The BS serves large number of user at a time in case of MU-MIMO [4]

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Conversely, a massive MIMO (mMIMO) system has an exceptionally huge amount of antennas [5, 6]. The mMIMO offers spatial multiplexing and beamforming techniques, allowing for the simultaneous transmission and receiving of numerous data values to multiple users, by utilising an extensive amount of antennas mounted on the BS. With this technique, wireless communication systems' coverage and data speeds are increased, interference is decreased, and channel capacity is improved [7–11]. The mMIMO has seen unheard-of advancements in both research and application, making it a key component of 5G wireless communications. There are two categories in which mMIMO is divided-

- **Centralized mMIMO**- The benefit of centralised mMIMO systems is that they have little fronthaul requirements and data-sharing overhead since they use a compact large-scale BS antenna array [12, 13].
- **Distributed mMIMO**- Distributed mMIMO systems deals with enormous amount of antennas dispersed spatially across a cell that is why they are able to offer all user equipments (UEs) with reliably good service by taking use of the autonomous fading of their signals, which gives them a significant diversity gain against shadow fading [13–15].

Distributed mMIMO is proposed to fill dead zones and offer a broad range in MIMO systems, hence improve the performance of cell-edge users [16]. Futher to improve the spectral eficiency and serving large amount of users cell-free massive MIMO (CF mMIMO) comes into existence beneath the umbrella of 6G. The concept of CF mMIMO, in which there are no cell borders, is suggested by combining the benefits of massive MIMO, distributed mMIMO, and Network MIMO technologies [17]. Figure 1 shows the over all layout of the research paper. Overall introduction of the CF mMIMO along with 5G, 6G and mMIMO is explained in the section of introduction. The details of the CF mMIMO under the time division duplexing (TDD) approach and frequency division duplexing (FDD) ways are covered in the section of the system model that follows. In this part, scalable (SC) CF mMIMO information is also provided. Type of technologies used for CF mMIMO communication sysytem are discussed and covered by the section of enabling technologies. Researchers are dealing with many research problems for development of the CF mMIMO commuications. Some of the challenges are discussd in the section of future research problems. At the last there is conclusion of the research paper.

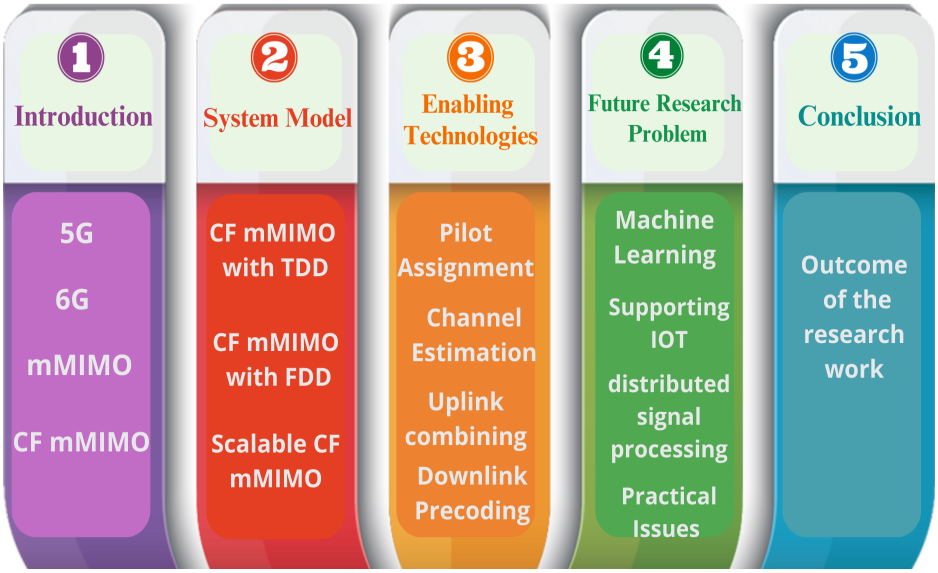


Figure 1: Organization of the research paper

2 System Model

The CF mMIMO is introduced in this section. TDD and FDD techniques as well as the SC CF mMIMO, which is an advanced version of the CF mMIMO are also discussed in the section. The mMIMO system model are represented in

Figure 2 where a) provides information about standard mMIMO system in which cells are defined BSs are mounted with huge quantity of antennas which communicate with UEs, b) represents distributed CF mMIMO in which The central processing unit (CPU) is connected to a spatially distributed network of access points (APs) via fronthaul and these APs communicate with UEs for reliable communication with higher spectral efficiency, and c) suggests structure for SC CF mMIMO in which virtual clusters of APs are formed for perfect reliable communication with UEs with less oveheads. [18, 19]. CF mMIMO is viewed as a possible option, wherein numerous wireless access points collaborate to utilise coherent signal processing to collectively serve customers. In CF mMIMO systems, there are still a lot of open-ended practical problems, of which implementing scalable huge access is one of the most crucial. The basic concept is to serve every user across a vast region by utilising a significant amount of dispersed APs coupled to a CPU. Specifically, every AP provides service to all users in either FDD or TDD modes of communication. Due to macro diversity benefit from the spread antennas, cell-free networks provide great consistent connection to all users than traditional co-located massive MIMO. Nevertheless, the system's scalability is limited [18], and decoding requires a large amount of power and computational resources, particularly for users getting low signal-to-interference-noise-ratios (SINR). This is so because it is expected that every AP will serve every user. In order to address the scalability issue, a user-centric dynamic cooperative clustering (DCC) system was considered in the paper [20]. Each user in this strategy is serviced by a sub-portion of the APs only.

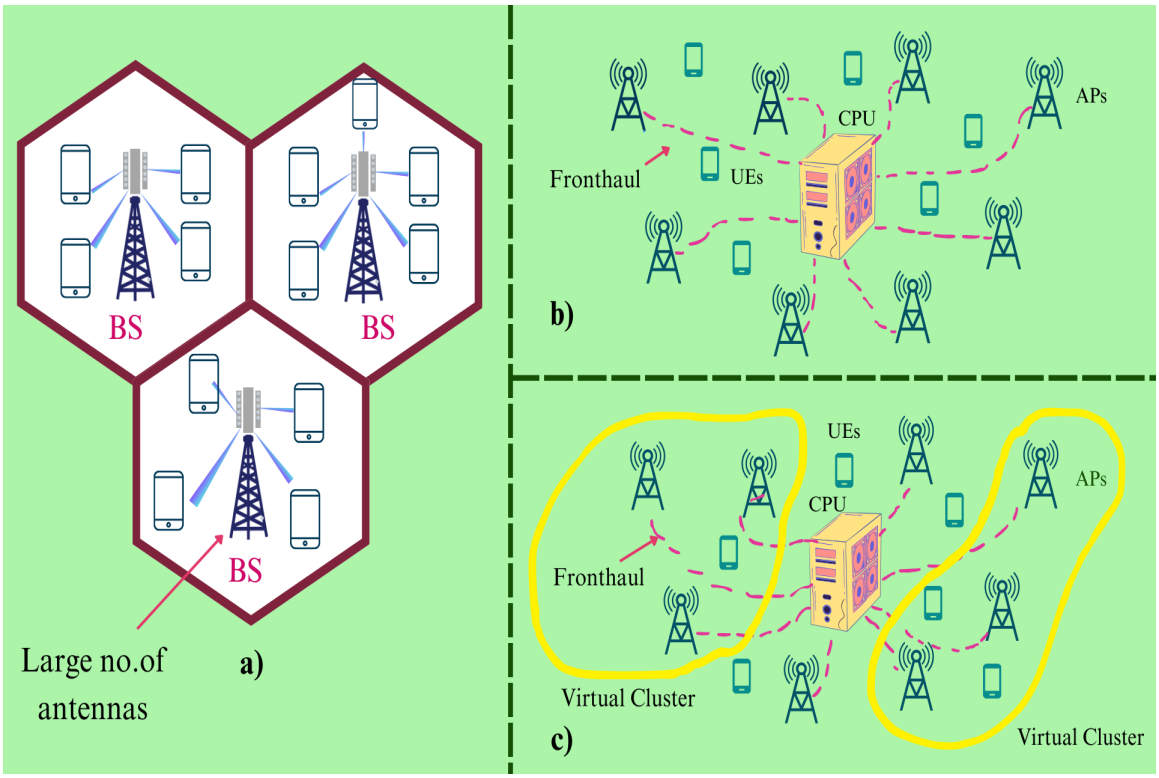


Figure 2: **a)** Illustration for standard mMIMO **b)** Illustration for distributed CF mMIMO **c)** Illustration for scalabel CF mMIMO

2.1 TDD for CF mMIMO

Figure 3 represents transmission period during TDD approach. The amount of time a channel stays steady is known as its coherence time. Uplink (UL) pilot time, UL data duration and downlink (DL) data time are indicated by τ_p, τ_u and τ_d respectively. The time that UEs send a signal to an AP, which helps the APs to obtain channel state information (CSI), is known as the UL. Following the estimation of the channel, signal detection [21–26] is carried out throughout the duration of the UL and DL data, respectively. A CF mMIMO network made up of 'A' dispersed APs which can serve 'k' single-antenna customers by each having 'N' antennas is considered. All APs are linked to a CPU.

Using uplink channel estimation, every AP obtains CSI between itself and every user on the network in TDD mode of communication. The CSI between A^{th} AP and k^{th} user is indicated as $h_{kA} \in \mathbb{C}^N$ moreover for the coherence time, the channel is assumed to be constant. The Rayleigh fading channel is denoted as [27],

$$h_{kA} \sim \mathcal{N}_{\mathbb{C}}(0, R_{kA}), \tag{1}$$

in above equation $R_{kA} \in \mathbb{C}^{N \times N}$ represents spatial matrix of correlation which is affected by both large-scale and small-scale fading. The large scale fading is represented between k^{th} user and A_{th} AP by $\alpha_{kA} \triangleq tr(R_{kA})/N$, where $tr(R_{kA})$ represents the trace of R_{kA}. Mutually orthogonal pilots are represented as $\rho_1, \rho_2, \rho_3 ... \rho_{\tau_p}$ are sent during τ_p interval under coherence time. Since the pilots are orthogonal therefore, $\|\rho_t\|^2 = \tau_p$ for $t = 1, 2, 3..., \tau_p$. The length of pilot is τ_p. These pilots are known at both receiving and transmitting ends. They are well known as training symbols [26] and used to get CSI. Since $k > \tau_p$ the pilots are shared by more than one user in TDD approach. The UL signal received at A^{th} AP is given by [27], with

$$Z_A^p = \sum_{i=1}^{k} \sqrt{P_k} h_{kA} \rho_{tk}^H + W_A^p, \tag{2}$$

where $P_k \geq 0$ represents power transmit by the k^{th} user, W_A^p represents additive white Gaussian noise which is independent and identically distributed (i.i.d) with zero mean and σ^2 variance i.e. $\mathcal{N}_{\mathbb{C}}(0, \sigma^2)$. The estimated channel, obtained by minimum mean square estimation (MMSE), is provided as,

$$\hat{h}_{kA} = \sqrt{P_k \tau_p} R_{kA} \phi_{tkA}^{-1} z_{tkA}^p, \tag{3}$$

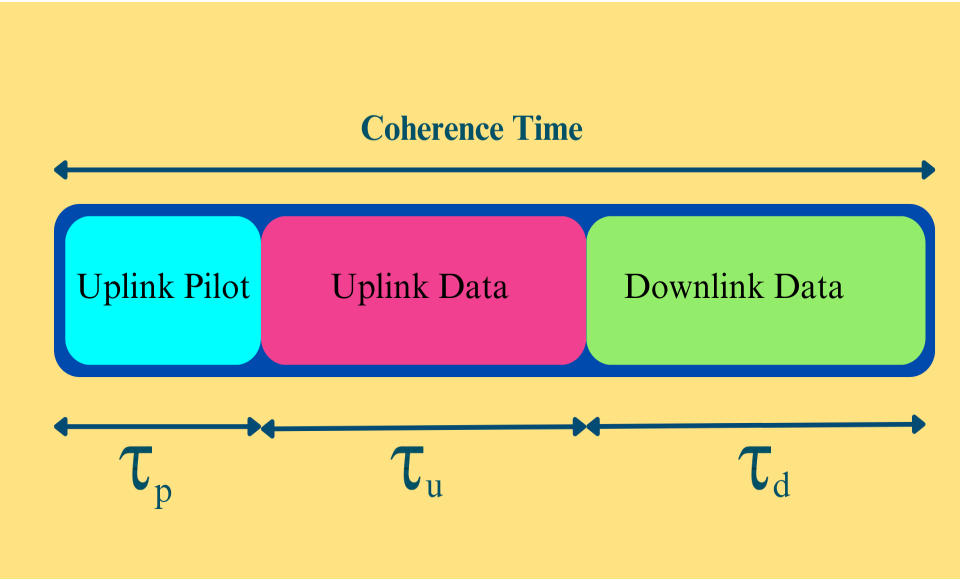


Figure 3: Cf mMIMO with TDD approach

where,

$$\phi_{tkA} = \sum_{i \in R_{kA}} \tau_p P_i R_{kA} + I_N, \tag{4}$$

and

$$z^p tkA = Z_A^p \frac{\rho_{tk}^*}{\sqrt{\tau_p}} = \sum_{i \in S_k} \sqrt{P_k \tau_p} h_{iA} + w_{tkA} \tag{5}$$

Now after getting the information of CSI the received signal during UL data transmission is given as,

$$z_A^d = \sum_{k=1}^{K} \sqrt{P_k} h_{kA} s_k + w_A^d \tag{6}$$

where $z_A^d \in \mathbb{C}^N$ at A^{th} AP in UL data transmission, $s_k \in \mathbb{C}$ is the signal transmitted from k^{th} user consists of P_k power and $n_l^d \sim \mathcal{N}_{\mathbb{C}}(0, \sigma^2 I_N)$. The primary difficulty in implementing cell-free networks is getting hold of accurate enough CSI to enable the APs to send and receive signals simultaneously to and from every UEs and to get rid of interference within the spatial domain. Given that the number of APs determines the feedback burden, the traditional method of deploying DL pilots and allowing the UEs to report channel estimations is not scalable. Consequently, channel reciprocity can be used in TDD mode to reduce the signaling overhead such that each AP needs to do is to calculate the UL CSI.. To go for this scenario FDD comes into existence.

2.2 FDD for CF mMIMO

The usable frequency spectrum in an FDD is split into two distinct bands: one for data transmission vis UL frequency channel and the other for data reception via DL frequency channel [28]. To avoid interference, a guard band (Frequency Gap) is placed between these two bands, as depicted in the Figure 4. For the following reasons, FDD based cell-free mMIMO systems [29] are an appealing substitute to take into account: i) While TDD is preferred at sub-6 GHz massive MIMO, FDD may be equally good in millimetre wave (mmWave) bands because the angular parameters of the channel are mutually beneficial across a large bandwidth [30], ii) FDD systems lack DL training symbols, which may prevent users from acquiring instantaneous CSI and thereby degrade system performance in detecting as well as decoding the intended signals, and iii) FDD provides lower cost and greater coverage.

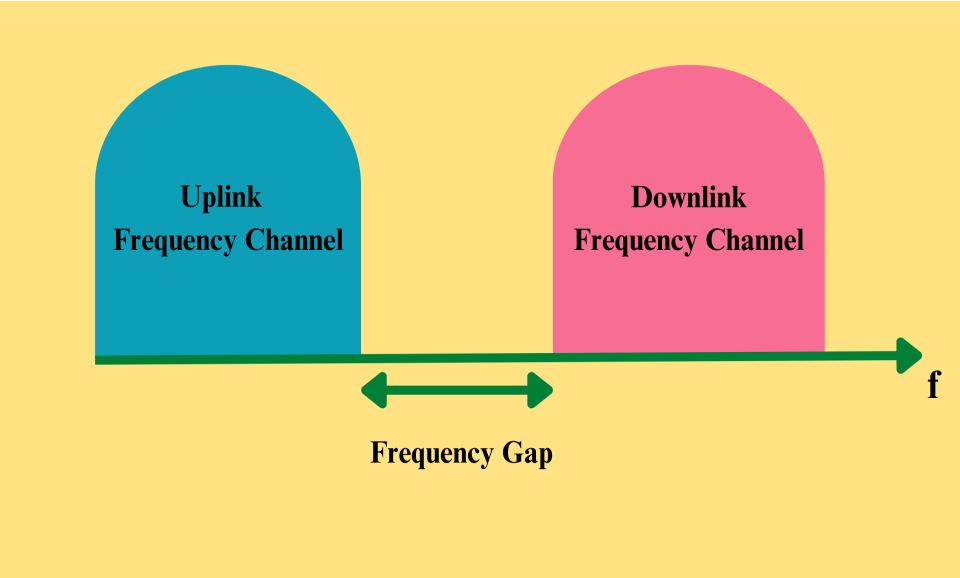


Figure 4: CF mMIMO with FDD

Since channel for uplink and downlink have different frequency. Therefore, small scale fading coefficents are differnt for uplink and downlink. The channel between A^{th} Ap and k^{th} user is given by [27],

$$h_{kA} = \sqrt{\frac{1}{P}} \sum_{p=1}^{P} \sqrt{\beta_p^{kA}} \alpha_p b(\phi_p) \tag{7}$$

where β_p^{kA} is the large-scale fading coefficient during path-loss and shadowing, $\alpha_p \sim \mathcal{N}_{\mathbb{C}}(0,1)$ provide complex gain with unit variance and zero mean, angle of arrival details are given by ϕ_p, and $b(\phi_p)$ is known as steering vector.

Table 1: Enabling Technologies use in CF mMIMO

Enabling Technologies	Proposed Solutions	References
Pilot Assignment Schemes	Location based methods	[32]
	Random pilot assignment	[33]
	Graph colouring based methods	[34]
	Hungarian algorithm	[35]
	Graph based methods	[36]
	Interference Aware User-Group (IA-UG)	[37]
Channel Estimation	Linear MMSE	[38]
	based on Deep Learning	[39]
UL combining techniques	Joint estimation and detection	[40]
	Expectation Propgation-based detection	[41]
	Partial Marginalization- based soft detection	[42]
	Sequential MMSE receiver	[43]
DL Precoding	Maximum ratio transmission precoding	[17]
	Enhanced maximum ratio transmission precoding	[44]
	Zero forcing (ZF) Precoding	[45]
	Local ZF Precoding	[46]

2.3 Scalable CF mMIMO

Figure 2 represents system models for CF mMIMO where C) provides information about SC CF mMIMO in which virtual clusters of the APs are formed for prompt reliable communication in terms of higher data rate, better spectral efficiency, lesser complexity, less frontal overhead etc. when large number of the users are required to accommodate within limited spectrum availability [18, 31]. Regretfully, the standard CF mMIMO approach is not SC for each of the four objectives listed below-

- **Precoding and combining** - The more users there are, the more difficult precoding and combining becomes because all APs compute for every precoding vector and combination vector for every k user.
- **Estimation of Channel** - Channel estimation is required for all k^{th} users by A^{th} AP. Therefore, as the number of users increases, so does the computing complexity.
- **Optimization of power**- Given that the centralised CPU is connected to every AP. As a result, centralised power optimisation is necessary, and complexity rises as the user grows.
- **Overhead in fronthauls** - More APs are required to accomodate large number of users which in turn affects fronhaul overhead.

3 Enabling Technologies

The brief information about enabling technologies like channel estimation, pilot assignment, uplink combining techniques and downlink precoding techniques are given in the Figure 1. Most of the information can be fetch from the Table 1.

A three-step technique for first correlation, pilot allocation, and cluster creation was proposed in [18]. To realise the potential performance of CF mMIMO, CSI acquisition is crucial. Pilot reuse is unavoidable due to the system's vast user base and the orthogonal pilot's short lifespan. On the other hand, pilot contamination will make the system less effective. The random pilot assignment system examined to enable each user to select a pilot sequence at random that results in severe pilot contamination. Subsequently, a greedy algorithm-based pilot assignment approach was presented in with the aim of progressively updating the lowest uplink attainable rate for every user [17]. Prior to applying the greedy pilot assignment algorithm [32], the location data was used in the pilot assignment . It can only, however, support a restricted throughput performance. A pilot assignment technique based on graph colouring was presented in [33] with the aim of drastically lowering pilot contamination. It should be noted that [32], [33]all share the goal of

creating suitable regulations to prevent pilot reuse by adjacent users.

Pilots are used to fetch CSI. Different kinds of tactics can be used to categorise channel estimation. In a completely centralised channel estimation scenario, the CPU estimates the channel after receiving the pilot signals from the APs. When taking into consideration a centralised channel estimate, users' privacy is compromised because the CPU should be aware of their location data. Differential privacy (DP)-based channel estimation techniques were presented for CF hybrid mMIMO systems in order to prevent revealing users' location or privacy [47]. Another way is to do channel estimating locally at the AP in order to estimate the channels of its connected users. MMSE estimator is frequently used in the channel estimate stage if Rayleigh fading channel is taken into consideration.
Effective methods for detecting data are greatly sought in large-scale, intricate networks, including CF mMIMO systems. The broadcast data (x) for uplink detection is approximated using the noise power, channel matrix, and received signals. Early attempts were made in this area using centralised methods, in which the CPU performs the detection using the data signals provided from all APs and the pilots that were received [17]. But when the scale of the network increases, the processing burden of such a centralised detection approach becomes unaffordable.
As a part of uplink combining techniques in [38], the spectral efficiency (SE) of three dispersed receivers and one centralised receiver with varying levels of AP cooperation was compared. Here is how these levels are described:

- **Level 4**: Each AP's signal and pilot are received by Level 4's CPU, which is a fully centralised receiver. To estimate the channel and find data, the CPU makes use of these signals.
- **Level 3**: It collectively deals with two stages. Each AP first calculates the channels before detecting received signals using a linear MMSE detector. Next, the CPU uses the large-scale fading decoding (LSFD) approach to gather the discovered signals for joint detection across all UEs.
- **Level 2**:This is the special case of Level 3. All UEs' joint detection is accomplished by the CPU by averaging their local estimates. Therefore, there is no need for channel statistics to be sent over the front-haul to the CPU.
- **Level 1**: This level is a completely distributed method in which local channel estimations are used at the APs to perform data detection. It is not necessary to send any data to the CPU.

Maximum ratio transmission (MRT) beamforming was studied in earlier studies to handle single-antenna APs and preserve system scalability [17]. Then, a modified MRT precoding was suggested [48] in order to remove interference with oneself without requiring action from the receivers; however, it necessitates CSI exchange between the APs, which is not SC when there are a lot of users and APs. As an alternative, the enhanced MRT precoding approach was put forth in [48], wherein the precoding vectors are constructed using only the individual channel estimates of each AP.

Figure 5 represents the achievable bit error rate (BER) for distributed expectation propogation detector (DEEP) in contrast with detectors studied in [38]. In the paper [38] number of distributed APs = 17, number of APs=8 and number of users=16. The Figure 5 shows that the suggested distributed EP detector works better than the centralised Level 4 detector with T = 5 iterations and is on par with the Level 1 detector using a single loop of EP.

Additionally, we assess how well the distributed EP detector performs in SC CF mMIMO systems in comparison to alternative receivers. The distributed EP detector works better than the centralised and distributed MMSE detectors, as seen in Figure 6. The parameters for both the plots are same.

4 Future Research Problems

Even though CF mMIMO has been studied for a while, there are still certain problems that need to be resolved. In addition, a number of fresh technologies have been put out as wireless communications' enablers. Thus, a lot of academics are working to integrate these technologies into large MIMO that doesn't require cells. We will go into further detail about a number of potential applications and problems with CF mMIMO in this part, covering a number of new technologies and real-world problems.

- **Reconfigurable Intelligent Surfaces (RIS)** - The SE can be greatly increased by Reconfigurable Intelligent Surfaces (RIS) in order to satisfy the strict specifications for 6G networks for wireless communication. The

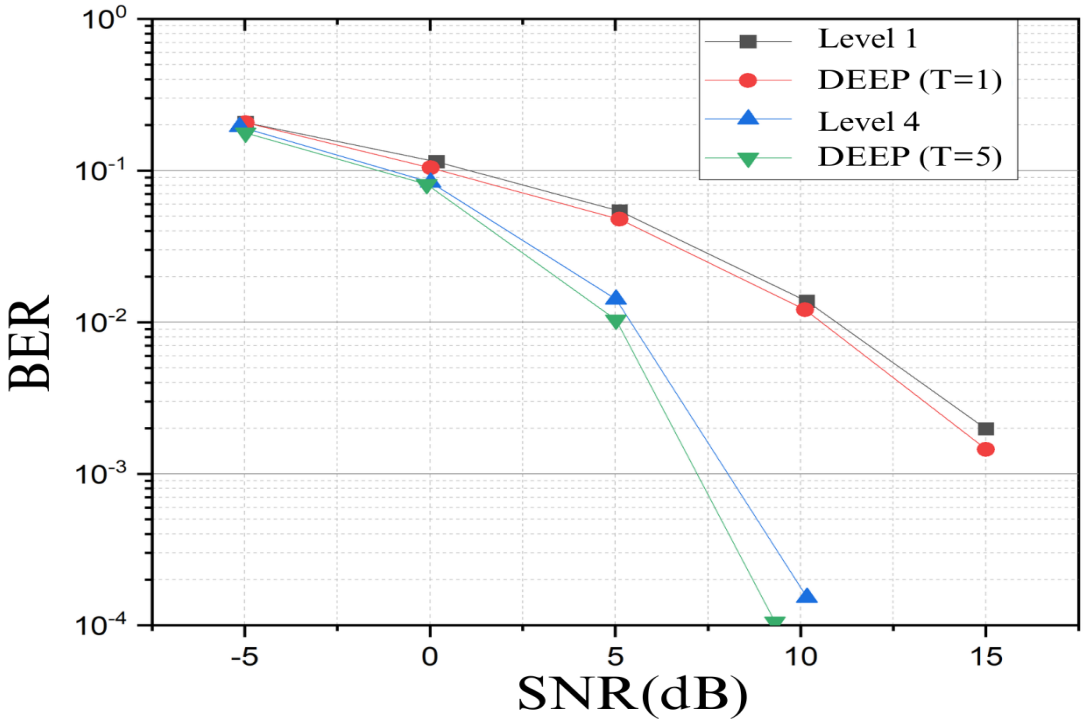


Figure 5: Comparing the BER performance of several detectors in standard CF mMIMO systems

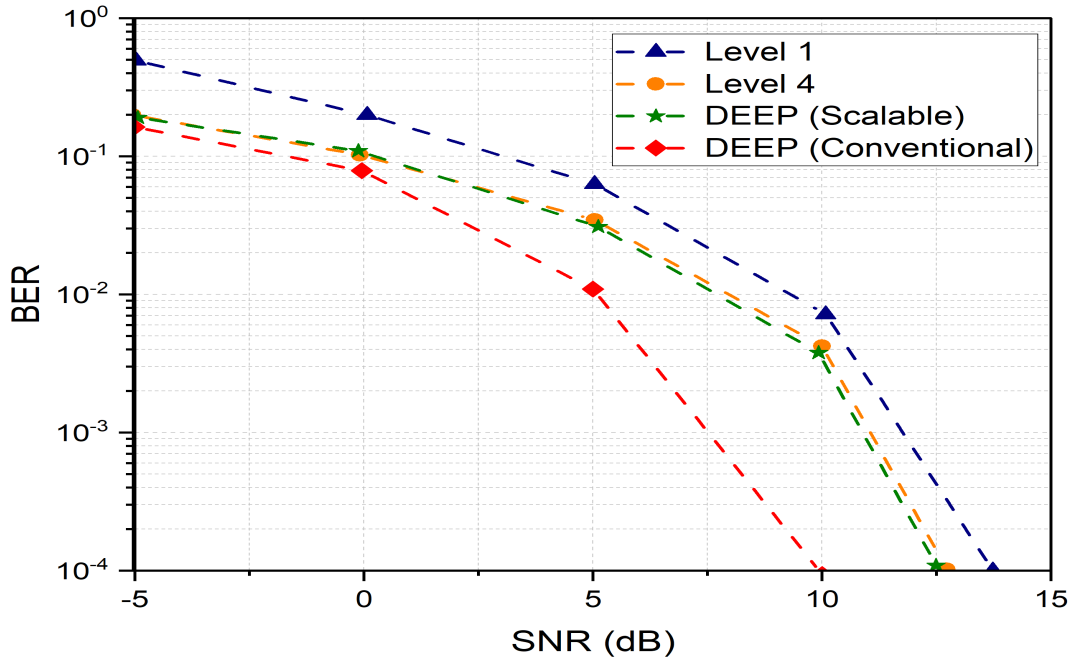


Figure 6: Comparisons of various detectors' BER performance in SC CFmMIMO.

purpose of a RIS with numerous reflective components is to change the direction of the beam reflected from surface for reliable communication [49–51].

- **Machine Learning** - Physical layer communications, including power regulation, MIMO detection, channel estimation, and CSI feedback have recently seen the application of machine learning (ML) [52, 53]. As a result, some researchers thought about enhancing the CF mMIMO system's performance with the ML tool.
- **Internet of things (IOT)** - Recent research has looked into using cell-free massive MIMO to support IOT systems. CF mMIMO can perform better than IoT network that is enabled by co-located massive MIMO systems by taking use of the macrodiversity gain and improved coverage brought about by distributed antennas. Thus, it is intriguing to think about and investigate the application of CF mMIMO to IoT [54].
- **Dispersed Signal Processing** - To reach the desired performance, designing a scalable and inexpensive algorithm is vital. The performance is distant from the centralised algorithms, despite the fact that a number of dispersed signal processing techniques have been studied for the receiver and precoder design [38].
- **Practical Issues** - The implementation of a less-complexity, less-cost deployment strategy is necessary to accomplish ubiquitous CF mMIMO. As a result, network design built on a unique hardware platform ought to be taken into account. Both the fronthaul and deployment costs may be decreased. To achieve ubiquitous cell-free massive MIMO, it is therefore promising to construct methods for signal processing that are based on radio strip technology [55].

5 Conclusion

An extensive analysis and overview of the signal processing formulae used in cell-free massive MIMO systems were provided in this paper. Channel estimate, UL combining and DL precoding, power regulation and allocation, user association and pilot assignment, and other recent advances were emphasized. Additionally, certain cutting-edge technologies that can enhance CF mMIMO, like federated learning, RIS, and ML, were introduced. The superiority of massive MIMO systems and dispersed antennas are inherited by cellfree massive MIMO, is an extremely promising technology that will make 6G wireless networks possible due to its uniform connectivity for all users and excellent performance.

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DETECTION STRATEGIES FOR PREVENTING CYBER ATTACKS IN SMART GRIDS: A COMPREHENSIVE LITERATURE REVIEW

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Abstract

This paper presents an inclusive review of various detection strategies employed to safeguard smart grid systems against cyber-attacks. This paper provides an overview of multiple researches done in the field, uncovering the numerous threats posed to the smart grid and the techniques and prevention strategies used to counter these threats. This paper provides the insight in-depth analysis of recent case studies and academic research, the paper sheds light on the challenges faced in implementing effective detection strategies while ensuring minimal impact on the smart grid's operational performance. This paper also discusses the modeling consumption behavior and the energy profiles of several appliances. Finally, the cost efficiencies and comparison of the three consumption patterns based on the values of consumption indicators is discussed.

Keywords

Smart grid technologies, cyber-attacks, detection strategies, smart metering technologies, operational performance etc.

Introduction

An electrical grid which can perform numerous operations and energy measures like advanced metering infrastructure is called as a Smart Gird. In a smart grid, monitoring and management of the electricity transportation from generation to the end users varying demands are met. There is a growth of renewable power generation distribution which in turn increase the number of equipment’s used in the field of communication, thus leading to making such generation systems more vulnerable to cyber-attacks. Cyber-attacks on smart grid safety include malware propagation, the breaching of delicate customer data by rival, vulnerabilities in cyber systems and malfunctions in distributed control devices.

Firewall systems are a necessary countermeasure against cyber-attacks. A firewall is a network safety device that monitors and sieves incoming and outgoing network traffic and determines through specific rules the authorized internal and external communications [1].

Even though the awareness among government, and private sector about the cyber loop holes of the electric grid is increasing, it is still difficult to predict the likelihood and outcomes of a

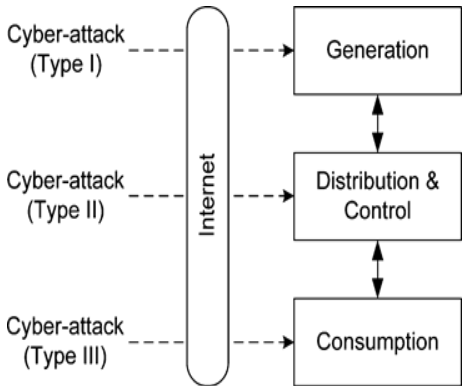
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cyberattack. This results in a confused and indecisive market for stakeholder in the electric sector, as they face problems in determining which funds to make beyond the minimum required for compliance with compulsory standards. This leads to, current risk management approaches which are generally qualitative or heuristic [2].

The overall reliability of smart grids depends upon cybersecurity. The false data injection (FDI) is the most critical among the possible cyberattacks. Opponents or rivals can launch such attacks to introduce malicious measurements by compromising smart meters. These attacks can mislead the power grid algorithm, leading to complete collapse in large areas. Hence, detection of attacks is the most necessary step to minimize damage that FDI may cause. FDI detection's efficiency have a deep impact on the overall performance of the smart grids. Feed-forward neural networks have been used on FDI detection, but they did not yield good outcomes as the spatiotemporal correlation of data is not considered in training [3].

Any area of a power system, including production, transmission and control, and usage, could be the aim of a cyber-attack effort. As a result, they can distinguish between three distinct cyberattack scenarios based on the intended target, as illustrated in Fig. 1.

Fig.1. Types of cyber attacks on the electric grid through the Internet.



Cyberattacks target power facilities with the intention of seizing control of or interfering with generator operation. There are several stories suggesting that similar attacks have occurred in the past, despite the fact that they are highly skilled and resource-intensive. For instance, the Central Intelligence Agency announced in January 2008 that it was aware of four hacker-caused disruptions to the power supplies for four cities [4].

Advanced metering infrastructure (AMI) and other smart monitoring systems rely on centralizing consumer personal consumption data at their smart meters, which raises privacy concerns. A Dutch court decision from 2009 mandates that privacy concerns be taken into account while utilizing smart meters. Similarly, NIST in the US mandated that SG communications use a "privacy for design"

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methodology. If the smart meters are sufficiently authenticated, these privacy problems might be resolved. Such a system should, however, take into account the smart meters' relatively constrained resources, such as their little memory and processing power. Therefore, any smart grid communication authentication system should be designed to minimize its impact on the already limited resources for smart metering. Stated differently, SG communication necessitates that a secure authentication framework at least double the amount of communications that are sent between smart meters. [5].

Because of its clever, intelligent, and interactive characteristics, smart grid technology (SG) has replaced conventional electrical grids, increasing dependability and efficiency. In addition to providing power suppliers with distributed control, SG meets the demands of both present and future customers. Researchers and engineers in the fields of communication and electric power generation have been particularly interested in SG in recent years. Another name for SG is the "upcoming grid." It is an improvement to traditional electrical power grid that combines digital calculations and communication technologies to deliver electricity in a secure, reliable, and efficient manner and to facilitate information exchange between utility companies, power generators, and electric power consumers. Here are a few significant features that SG offers:

1. Self-healing: SG is able to recognize, evaluate, and react to errors quickly by taking appropriate and wise action to recover from such errors.
2. Encourage and involve the customers: By offering interactive choices and data, the SG helps customers choose the best possible plan and manage their electricity consumption accordingly. Customers are able to create more efficient and economical strategies for themselves in this way.
3. Attack resistance: SG is able to fend off both physical and virtual attacks.
4. Improvement in power quality: Since consumers' main demand these days is constant voltage, SG can maintain it. This can improve power quality and lessen loss of commercial efficiency as abrupt voltage variations can damage electric appliances.
5. Support all generation sources and storage options: Renewable energy sources like solar, wind, and green electricity cannot be integrated into a conventional power grid. Whereas, SG is able to incorporate and adapt to these renewable resources. [6].

Literature Review

Ref No.	Proposed Work	Technique
[7]	The present research offers a comprehensive examination of SG, encompassing its fundamental components, diverse cyber security and other related issues, current communication protocol techniques and strategies, and the structure of SG.	A brief overview is given in the paper regarding SG system and its components like AMI, SCADA system, etc.

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[8]	The multiple cast communication and authentication requirements for smartgrid are identified in this study. According to these requirements, it is determined that one time signature based multiple cast authentication, with its short authentication time and low cost, is a viable solution.	An OTS scheme TSV technique is proposed to facilitate multiple cast authentication in SG.
[9]	This article proposes a role-based architecture and a novel method for network access control. Fresh idea expands network access control from one safety domain to numerous domains for networked micro grids.	Increasing the security in power grid has been proposed in this article.
[10]	In this research, the authors offer a privacy-enhanced smart metering architecture designed. This protocol encrypts each measurement while letting the electricity provider access totality of the associated decrypted values. Method being utilized allows for direct communication and data sharing between electricity providers and end consumers while safeguarding their privacy.	A privacy-aware protocol method known as additively homomorphic encryption is used. It is applicable to the collection of smart meter information.
[11]	In order to detect optimal attack sequences for a multiple step game among attacker and defense given specific objectives, this study employs reinforcement learning. An analogy among multiple step attack and one shot attack is presented to highlight importance of the multiple step attack.	For two person zero sum attacker defender multiple step dynamic game, a new solution is proposed in this paper, in smartgrid safety based on reinforcement learning.
[12]	In this paper a better method of computing the similarity of the verified alerts is suggested. To create a strong Alert Cluster, their method combines the clustering technique with the supporting evidence (vulnerability data). Their objectives are to lessen numerous pointless warnings and raise caliber of warnings that were provided to researchers.	Robust Alert Cluster to cluster alerts, technique is used here.
[13]	In this paper, they represent as a Gaussian process the harmful and/or aberrant occurrences that will jeopardize the confidentiality of smartgrid consumers. An innovative quick warning system is suggested for foreseeing harmful occurrences in smartgrid network based on this paradigm. Through computer-based simulations, they evaluate the proposed early warning system's efficacy.	A framework for predicting harmful attacks is presented here, which may arise in emerging SGs.
[14]	Information infrastructure discussed in this article is decentralized, IP-based, data-centric, and capable of supporting the next-generation grid and its innovative applications in a reliable, secure, and affordable manner. Power applications have specific requirements, like safety, distributed data resources, latency delicate data transactions, and actual time event notification. These requirements are undertook in the proposed architecture.	It demonstrates deconcentrated and data centric information infrastructure for next generation power grid and its benefits.

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[15]	The notion of a "smart community," a paradigmatic class of cyber physical systems comprising cooperative objects, is introduced in this article. It outlines the smart community's architectural design and explains how to set up dependable, secure networking between houses.	Here, the smart community has been introduced as fresh use of IoT.
[16]	A strategy is proposed to prevent such failures by creating enough power disjoint communication links among power nodes and the control center. Connections are optimized to maximize robustness using a maxflow problem approach. Simulation outcomes shows that proposed strategy is both computationally and optimally efficient, and numerous power disjoint routes cannot exceed numerous node disjoint routes in network.	A computationally efficient technique is proposed in this paper detecting an optimal relationship configuration between communication network and powergrid, in a way that system soundness can be amplified.
[17]	The goal of this work is to address the issue of cyberattacks by developing and implementing an intelligent module known as the analyzing module (AM) in multiple smart grid layers, which provides a distributed intrusion detection system for smart grids (SGDIDS).	A new architecture technique, SGDIDS, is used here to enhance cybersecurity of smartgrid by utilizing a ranked and distributed intrusion detection system in wireless network.
[18]	Various cyber safety countermeasures must be implemented on the heterogeneous smart grid in accordance with the availability of computational resources, temporal communication restrictions, and sensitive data. Confidentiality, authorization, integrity and authentication of shared data are core goals of a cyber secure smart grid, along with its main security concerns and difficulties.	With the development of smart grid comes additional cyber security problems due to essential requirement of an ICT based safe communication layer which is used to connect all the actors in network.
[19]	It is crucial to conduct research on the best ways to use non-conventional energy in supply demand framework of upcoming smartgrids. With regard to home smart grids outfitted with a centralized non-conventional energy source, they specifically take into account cost-effective energy scheduling. Their scheduling issue aims to: i) quantify the best way to use renewable energy; ii) assess how volatility of non-conventional energy affects that balance.	Investigation of the cheap energy planning for residential smartgrid equipped with centralized non-conventional source is conducted in this paper.
[20]	Here a novel model is presented based on mixed integer linear programming, where proposed optimization problem with less computation burdens coherently considers demand response of available controllable appliances. In order to account for the inherent stochastic behavior of non-conventional energy sources and uncertainty surrounding electric load prediction, the model takes into consideration suitable stochastic models.	This paper discusses the necessity of taking eco-friendly technologies like RES, SG, and EV into account during the design stage of an efficient electric power system, given the rapid development of these technologies and their growing acceptance in the economy and society.
[21]	This article analyses the results of selecting specific preference models, planning frameworks, and computing mechanisms for RDSA and finds inconsistencies between proposed model formulations and optimization strategies.	A range of methods are discussed here which are used to construct complete demand side aggregation system, considering actual world requirements.

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[22]	To increase economic performance of domestic energy usage, they present a novel framework for cost productivity based residential load planning in this research. Using a fractional programming strategy, they create a load scheduling algorithm that is cheap for demand side's the next day's bidding procedure and actual time pricing mechanism.	Here, a commercial concept is proposed as a metric of economic performance of consumption of electricity to maximize used benefit per unit cost.
[23]	Energy administration problem for two cooperative micro grids, each with a separate ESS and renewable energy generator, is considered in this study. Based on the discovered solution, they look into how energy cooperation between micro grids and their ESSs affects the total cost of energy. Then, using an offline optimization technique as inspiration, they offer online algorithms for the two cooperative micro grids' real-time energy management.	Here, they study energy administration problem through off-line optimization.
[24]	Since trading energy with other nearby users is more advantageous, users with excess generation compete with one another to sell their individual excess power to their neighbors. A game-theoretic approach is used to represent the interaction between users with excess creation.	Load check algorithm for DSM is proposed here.
[25]	This study looks at problem of planning for residential users on smart grid. For residential customers, they propose a planning strategy that achieves desired tradeoff between payments and discomfort provided that the electricity provider announces price in advance. The power scheduling optimization problem uses both continuous and integer variables.	An optimization planning scheme is proposed here to implement demand response in residential unit when the electricity price is announced in advance.
[26]	Authors of this work create a HEM 6 controller using four heuristic algorithms: Genetic Algorithm 8 (GA), Binary Particle Swarm Optimization (BPSO), Wind 9 Driven Optimization (WDO), and Bacterial 7 Foraging Optimization Algorithm (BFOA). All 11 of the chosen algorithms are evaluated in Actual Time Pricing scenario while accounting for the top 12 household appliances. Based on simulation results, every algorithm in the HEM controller minimizes PAR and lowers the cost of electricity.	In this article, HEM controller for residential energy administration in smartgrid is presented here.
[27]	In this work, they introduce the general home energy management control system (HEMCS) to schedule the household load effectively and incorporate RESs. Costing of energy computation uses both inclination block rate schemes and real-time pricing (RTP) because relying only on RTP increases the risk of creating peaks during off-peak hours, which could negatively impact the entire power system.	Here, heuristic based techniques for DSM and energy productive integration of RESs in SG has been provided.

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[28]	The study's recommendation is a hierarchical multi-agent control system with an intelligent optimizer, to reduce the amount of energy used without sacrificing the comfort of the users. To accomplish the overall control objectives, four different types of agents—the switch agent, central coordinator-agent, local controller-agent, and load agent—collaborate. The integrated building and micro grid system's intelligence is increased by the use of particle swarm optimization (PSO).	In this case, an intelligent multi agent control system with heuristic optimization is created, able to coordinate the various agents and the optimizer to accomplish the control objectives. Additionally, a GUI-based simulation platform has been created to give clients flexibility.
[29]	A study proposes a real time planning and energy storage control solution for optimizing load scheduling and energy storage in a residential setting with integrated renewable generation. The aim is to minimize the total system cost within a limited time frame while taking into account various factors such as load intensity, delay requirements, and battery operational limits and costs. They use Lyapunov optimization to offer a solution for this stochastic problem, demonstrating that load planning and energy storage control can be decided with closed-form solutions for straightforward implementation.	A closed form for scheduling per slot and energy storage decisions has been provided.
[30]	The incorporation of renewable energy has created new power quality concerns, which are subject of a thorough research analysis in this article. The essay is divided into two sections: 1) A definition of the power quality issue. The problems with electricity quality caused by wind turbines and solar photovoltaic (PV) systems are outlined. 2) Current methods for enhancing electricity quality.	This paper conducts a thorough review of the literature regarding new power quality issues arising from incorporation of renewable energy sources into powergrid.
[31]	This study examines two different strategies for lessening the intermittent and time-varying nature of renewable energy production. Storage can be used to balance out fluctuations in renewable energy production over time. Concept of cooperative energy exchange between distributed generation and dispersed sources constitutes the second method. This study looks at the trade-off between these approaches.	To lessen the uncertainty associated with harvesting renewable energy, they investigated the advantages of energy storage and collaboration amongst interconnected MGs in this work.
[32]	The relative performance of HEM controllers embedded with heuristic algorithms, such as the amplified differential evolution algorithm, harmony search algorithm, and harmony search differential evolution, is assessed in this work. Performance of HEM system is improved with the incorporation of RES in SG. However, the integration of RES allows the electrical user to use the appliances during peak hours despite the fact that peak hour electricity consumption typically causes peaks and raises costs.	With the introduction of the SG concept, appliances are now smart enough to control the power consumption of smart homes and coordinate through EMC.

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[33]	In this article by planning the schedulable loads at less-priced intervals and taking into account the operational dynamics of non-plannable loads and RER availability, the IREMS achieves the goal.	Presentation includes an IREMS for smart buildings that integrates data and transmission technology, smart appliances, and internal RER power production.
[34]	In this study, the performance of a home energy management controller based on the genetic algorithm (GA), and ant colony optimization (ACO) heuristic algorithms is compared. In this sense, they present a general demand-side management (DSM) architecture that connects residential and smart areas via a wide area network. Additionally, many knapsack problems are used to carry out problem formulation. A combination model of inclination block rates and time of use tariffs is used to price energy.	The EMC model has been presented using two heuristic algorithms (GA and ACO), and the proposed model uses aggregate pricing models, TOU tariff and IBR model for electricity bill computation.
[35]	In this research, the authors first present a broad framework for an energy management system in local area network based on smart grid, and they next suggest an effective strategy for managing household energy use.	An approach for power scheduling is presented by combining RTP and IBR together, their approach could satisfy all the benefits not only for residents but also for utility companies.
[36]	A new model can estimate carbon emissions from power systems with high renewable energy use, calculating the least-cost dispatch from every technology and carbon emissions at every hour. This system can create a low-carbon portfolio that provides over 99% of yearly delivered load from non carbon sources while reducing electric power sector carbon emissions by 80%.	There has been a description of a new grid integration model based on Monte Carlo that can plan and provide system analyses.
[37]	The development of grid-tied, customer-owned wind and solar microgrids is outcome of the improvement of renewable energy technology. However, the main grid becomes more complex as outcome of smart grid's integration of renewable energy-based sources. Precise synchronized information interchange between micro grid, main grid, and users will be crucial to the scheme's success. The smart grid's ability to implement intelligent judgements will depend heavily on the interaction between these agents. Information on energy forecasts must be transmitted to the utility grid by the micro grids.	Idea of prosumer-based demand side administration has been presented. Here, appliances time of use have been applied as a technique of learning customer electricity demand pattern.
[38]	This study proposes a load-shifting-based DSM strategy to manage demand in future smart grids using a variety of equipment's, using a minimization problem formulation.	An evolutionary algorithm based on heuristics is devised to address the load shifting issue, and simulations on a smart grid comprising three distinct customer areas are conducted.

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[39]	This paper provides an outline of the possibilities of using game theory to handle pertinent and pressing outstanding issues in three cutting-edge fields related to smartgrid: communications, demand side management, and micro grid systems.	Application of game theory.
[40]	By actually carrying out the assault using real SCADA system hardware and software, this study investigates the attack. To comprehend the circumstances in which the attack is successful and efficient, Discrete-Time Markov Chain (DTMC) model is created.	To analyze the behavior of such attacks, two models have been developed: DTMC model and Mobius imitation model.

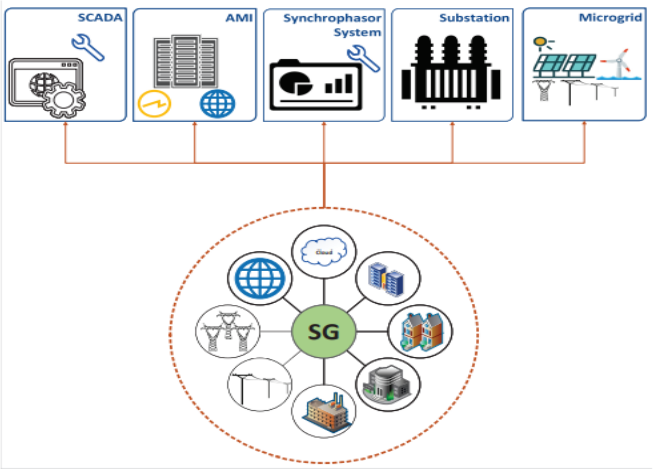
SG Technologies

With integration of many and heterogeneous technologies into the conventional electrical grid, the SG paradigm offers utilities and energy users substantial advantages through remote control and management capabilities. AMI, SCADA systems, micro grids, substations, and synchro phasor systems are a few of these technological entities (Fig. 2). The most important feature of the contemporary electrical grid is AMI, which allows for remote and real-time communication between customers and energy utilities. Specifically, there are three main components that make up AMI:
i) Smart meters
ii) Data collector
iii) AMI Headend.

Primary function of SCADA systems, which are an industrial type of system, is to observe and control automation operations. A communication network, a master terminal unit (MTU), remote terminal units (RTUs) or programming logic controllers (PLCs), and a human machine interface (HMI) are typically included. Since substations are used for both distribution and transmission, they are an essential component of the electrical grid's operation. Various parts, including RTUs, PLCs, and Intelligent Electronic Devices (IEDs), can be found in a substation. A micro grid is a self-sufficient distribution network that can function independently of the main electrical grid or in tandem with it. To run independently, micro grids typically use Distributed Energy Resources (DERs). Finally, phase angle, frequency, active power, and reactive power are only few of the measures that synchronized phase-phase systems often make from current/voltage waveforms. [1]

Fig. 2 SG Technologies

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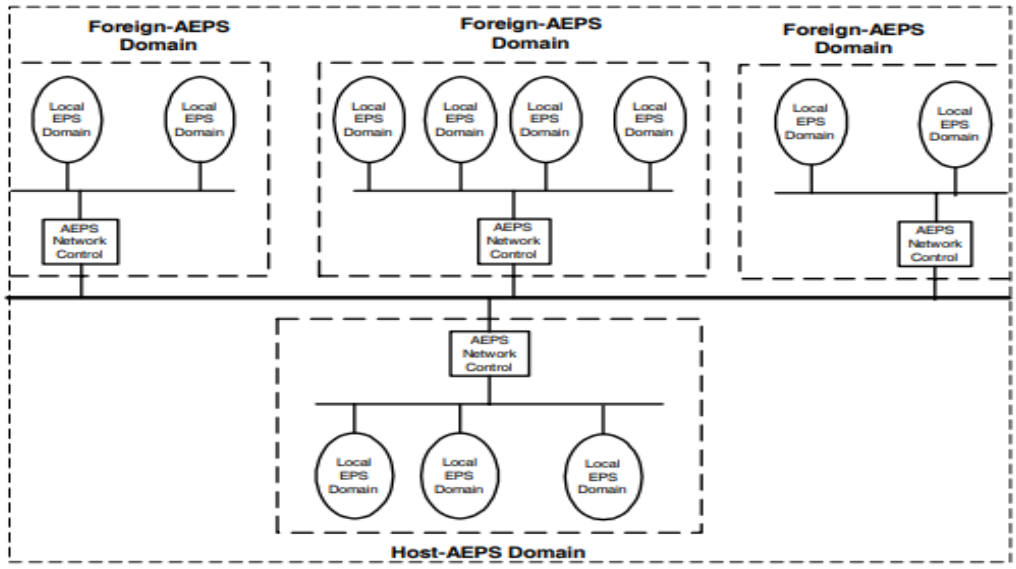
Security Management Architecture

The structure of the Smart grid Role based Access Control (SRAC), a novel ingress control system created for computer networks used by electrical utilities, is presented in this section. The SRAC greatly expands the role-based access controls that are currently in place to offer highly secure access control over network access in power systems that include micro grids. The architecture for SRAC network security management is displayed in Fig. 3. One Host-AEPS domain and several Foreign-AEPS domains make up this design. From the perspective of computer network users, these domains are defined as follows.

The network domain that the users ask for access initially belonged to is called the Host-AEPS domain, and the neighboring domains that the customers under consideration would like to use are called the Foreign AEPS domains. Every AEPS domain in this architecture has a single network control. According to this design, every AEPS domain has a network control center and a number of local EPS domains. A micro grid made up of one or more distributed electricity generators powered by alternative energy sources can be found within each local domain. The IEEE-1547 standard for integrating dispersed sources with electric power systems uses a taxonomy of domains that is compatible with those of electric power systems [9].

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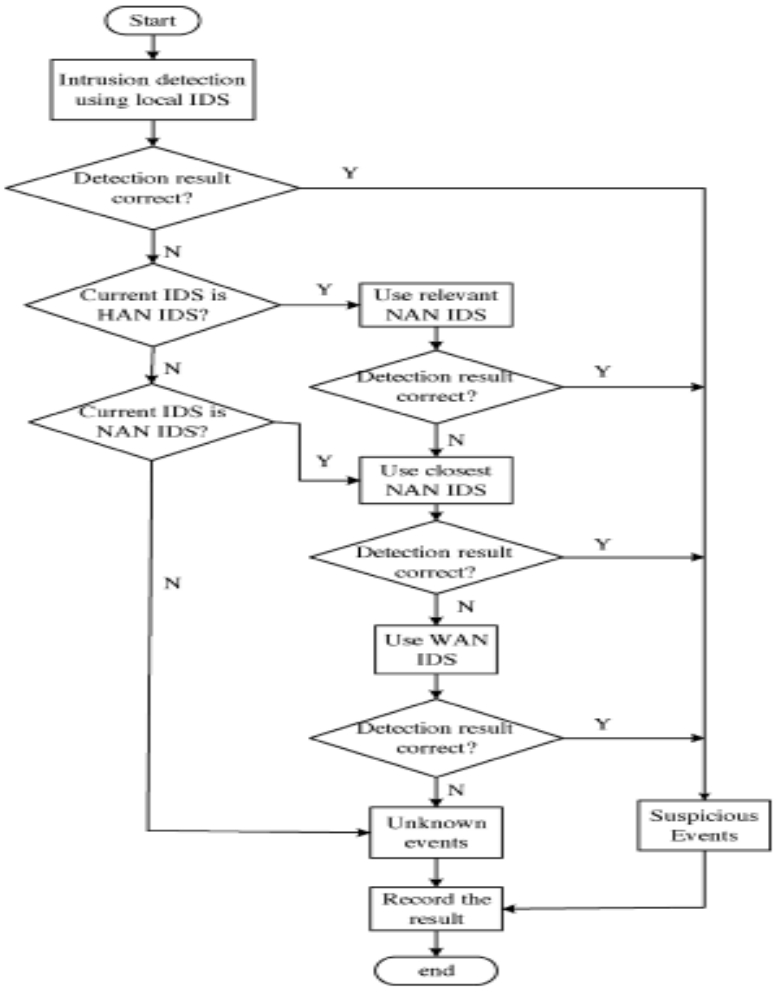
Fig. 3. Security management architecture



Detection Procedure in SGDIDS

Fig. 4. Detection procedure in the SGDIDS [17]

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Modeling Consumption Behavior

Table I displays the energy profiles of several appliances. It should be noted that differing designs can result in different rated powers for appliances of the same type. The power parameters are determined using data from online merchants of electric appliances [22].

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TABLE I
SMART HOUSE APPLIANCE SETTINGS I

Appliance*	Power(KW)	Utility per KWh	Demand per task(KWh)	ω^a	γ^a
A	0.8	1.25	3.2	2.5	25/32
B	0.15	10/9	3.6	20/9	50/81
C	0.15	20/3	1.8	40/3	200/27
D	0.3	25/18	2	25/9	25/18
E	1.2	5	0.6	10	50/3
F	0.2	10	0.3	20	200/3

*A. AC B. Fridge C. TV D. Lighting E. Microwave F. Kitchen ventilator

Cost Effectiveness of Different Usage Patterns

Table II presents a contrast of the three usage patterns based on the values of usage indicators. Type 3's cost effectiveness is significantly less than kinds 1 and 2's. This is due to the fact that in type 1, just the refrigerator is running; other appliances that have the potential to produce more utilities are not. When family members eat three meals a day as opposed to just two, it is more cost-effective since type 2 has a greater cost efficiency level than type 1. This is a result of our giving kitchen appliances significant utility generation capabilities. [22]

TABLE II
VALUES OF THE CONSUMPTION INDICATORS

Pattern	Demand(KWh)	Utility	Payment($)	C.E.
Type 1	13.642	34.7778	9.3802	3.7076
Type 2	14.458	40.7778	9.7314	4.1903
Type 3	3.252	3.9626	2.1412	1.8506

Conclusion

In this review paper, cyber-attacks in smart grid is examined. This paper too discussed about the detailed study of the current state of research in this field. The various research papers in the domain related to the cyber-attacks in smart grid are studied. This anuscript also presented the extensive review of the research work performed by various researchers in the concerned area.

The different Detection Technologies and Strategies by including detailed analysis of power consumption of different appliances due to various designs are discussed. Finally, the cost efficiencies and contrast to the three usage patterns based on the values of usage indicators is discussed.

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ISFT ST-157
A SURVEY ON TECHNOLOGIES, BENEFITS AND CHALLENGES UNDER 6G COMMUNICATION

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Abstract

The worldwide industrial and technological revolution is accelerating in the modern world. Sixth-generation (6G) mobile networks is now becoming benchmarks in terms of increased intelligence in the network, incredibly low latency, rapid network communication, and support for a vast array of interconnected applications. This article examines the newest trends as well as potential future developments that could support the operation of a 6G network. The purpose of this survey study is to present a concise and comprehensive overview of 6G mobile communication technologies. The paper provides information on emerging technologies, their advantages, and the hidden difficulties associated with the 6G communication system.

Keywords

3GPP, 5G mobile communication, 6G communication, cell-free massive MIMO, digital twin, Internet of Things, machine learning, visible light communication, wireless communication

Introduction

The fifth generation (5G) mobile communication technology has currently been implemented in numerous nations and large group of people have signed up for it. It's time for business and academia to turn their focus to the upcoming generation. At this juncture, considering the cutting edge today and a forecast for communications in the future are undoubtedly interesting. The evolution of the mobile communication has long history with enormous achievements as shown in the

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Fig **1**. The first generation (1G) analog cellular networks which began providing voice calls on a mobile device about 1980, are the source of the mobile telecommunications sector. Since then, the market has been introducing a new generation of mobile communications almost every ten years. About 1990, the second generation of digital cellular networks took the role of the first generation analog systems as digital transmission. Despite a number of rival systems, the Global System for Mobile Communications, or GSM [1], was extremely successful commercially and made mobile voice, brief texting, and low-cost data services available to over a billion people worldwide. The third generation (3G) systems [2], which are represented by Time Division Synchronous Code Division Multiple Access (TD-SCDMA), Code-Division Multiple Access (CDMA) 2000 and Wide Band Code Division Multiple Access (WCDMA) were designed, and initially implemented in 2001 to enable high-speed data availability at a rate of several megabits per second. They is done by utilising a groundbreaking technology called CDMA. With the opening of the commercial Long Term Evolution (LTE) networks in December 2009 [3], the first fourth generation (4G) mobile broadband service was made available globally in the cities of Stockholm and Oslo in Scandinavia. The innovative combination of multi-input multi-output (MIMO) and orthogonal frequency-division multiplexing (OFDM) powers the 4G system, which accelerates the adoption of smartphones and supports the trillion-dollar mobile Internet market.

In 2020 particularly, the benefits of 5G services and applications—like remote surgery, intelligent healthcare, virtual learning, remote work, autonomous vehicles, unmanned delivery, robots, and autonomous manufacturing are highlighted in the paper [4], [5]. Many countries have implemented 5G, and a significant amount of money has been spent on 5G infrastructure. Even so, there is a need to go above due to the general consumer trend in data usage. According to a) of

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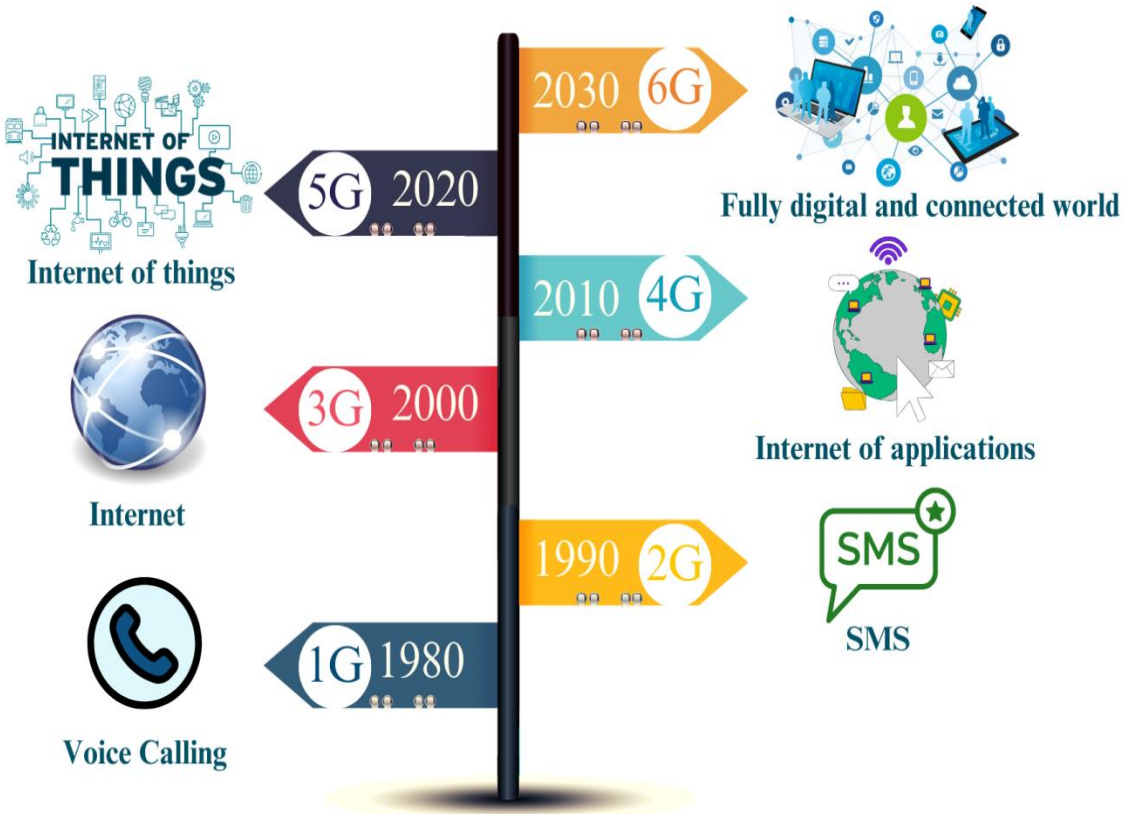


Fig 2, by 2030, monthly traffic volume would amount to 5016 extrabytes (EB), or 5016×1 million gigabytes (GB) in comparison to the 62 EB for 2020, this figure is extremely large in terms of data usage. The pattern of data use per month is shown in b)

Fig 2. This leads to the conclusion that, as the year goes on, data usage is exponentially growing. Thus, it is necessary to advance beyond 5G [6]. The technology will uplift to 6G by 2030 which constructs the fully digital and connected world.

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Fig 1. Evolution of mobile communication



Beyond 5G initiated the "6G Vision and Drivers" in October 2020 with the goal of giving early and timely guidance for worldwide sixth generation (6G) operations. The International Telecommunication Union Radio communication sector (ITU-R) voted to begin research in future technological trends for the development of International Mobile Telecommunications (IMT) at its meeting in February 2020. The difficulties and possibilities of terahertz (THz) communications in the creation and deployment of 6G networks were discussed by Rappaport *et al.* in [7]. The writers of the paper [8] afterwards gave a succinct explanation of vision and possible methods.

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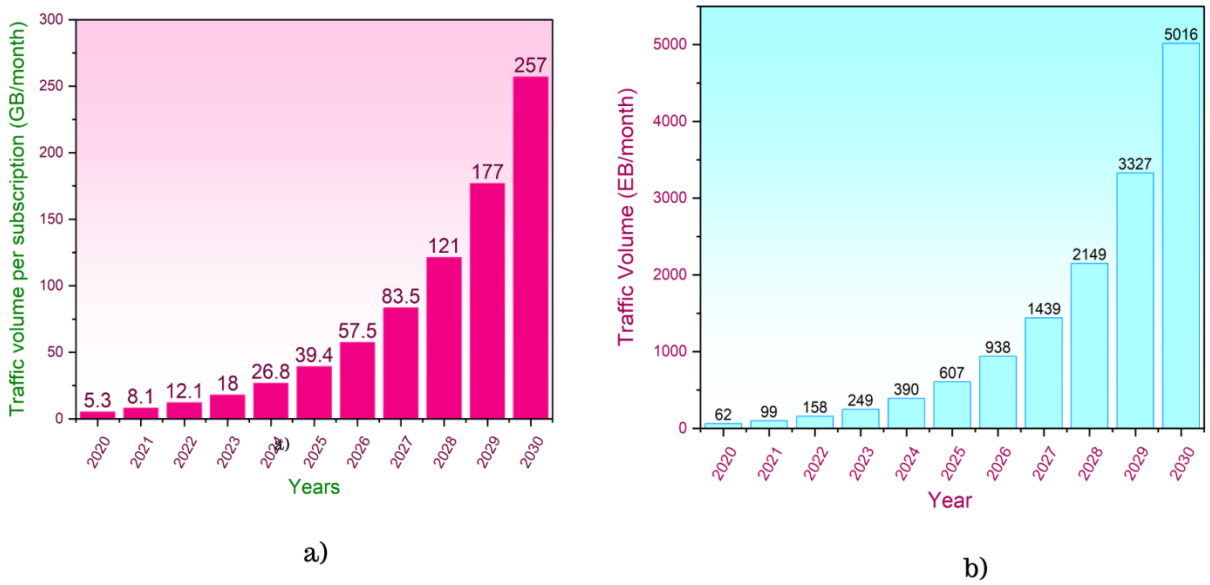
Letaief *et al.* covered potential technologies in the paper [9] that could allow for the ubiquitous provision of Artificial Intelligence (AI) services in 6G networks (also known as networking for AI) as well as AI-enabled design and optimization techniques for 6G (also known as AI for networking). In the paper [10], Zong and colleagues presented two potential 6G system designs and listed a number of 6G technologies, such as AI, holography, and photonics -defined radio.

As currently envisioned, 6G mobile communication networks should offer extremely high peak data speeds exceeding 1 Terabits/second. The end-to-end latency will be negligible, even falling below 0.1 milliseconds. Access to strong edge intelligence with processing times of less than 10 ns will be possible with 6G networks. With a speed 100 times faster than the current 5G networks, this might be a game-changer for people and businesses who want to send more data faster. It is anticipated that network availability and dependability will surpass 99.99999%. In order to support Internet of Everything (IoE), an exceptionally high connection density of more than 107 devices/km^2 is anticipated [11]. While support for extremely high speeds up to 1000 kmph is anticipated, 6G's spectrum efficiency will be more than five times that of 5G. There are many things that 6G allow us to do like telecommunication, extended reality, internet of things, autonomous driving, digital twin etc. There are many more road maps article which indicate that 6G is going to be upcoming technology [11]–[15].

The recommended article provides comprehensive details on the technologies, benefits, and challenges related to the upcoming 6G wireless generation of mobile communication. Section of ‘Introduction’ contains information on the development of wireless communication from 1G to 6G as well as data demand projections until 2030. This also provides information regarding the importance for going beyond 5G. Information about technologies under 6G is given in section of ‘Enabling Technologies under 6G’. The primary prerequisites for deploying 6G communication are discussed in the section. The collaborating technologies that lead to perfect 6G communication system are AI, quantum communication, digital twins, extended reality etc. The deployment of the 6G communication network is fraught with difficulties, several of which are covered in ‘challenges under 6G’. Section of ‘conclusion’ contains the proposed article's conclusion and future scope.

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Fig 2. Global mobile traffic and subscription details for the years 2020 to 2030. ITU-R Report M.2370-0 is the source [16]



Enabling Technologies under 6G

Numerous enabling technologies work together to create 6G. The purpose of this section is to examine 6G-enabling technology. The Figure 3 shows collection of enabling technologies uses in the section.

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Fig 3. Enabling technologies for 6G



Artificial Intelligence

Our lives have been fundamentally transformed by artificial intelligence (AI) and will continue to be changed. AI is being used in an increasing number of contexts and industries, including media, finance, industrial robotics, internet services, autonomous vehicles, and healthcare. The broad use of AI and its close collaboration with society and the economy have increased efficiency and yielded benefits. It will inevitably raise moral concerns and have an impact on the way society is now organised. People have experienced a considerable deal of distress due to ethical concerns brought about by AI systems, such as security hazards, discrimination, privacy leaks, and unemployment. Therefore, there is need to explore ethics regarding its use [17].

Quantum Communication

One of the three pillars of second-generation quantum technology is quantum communication,

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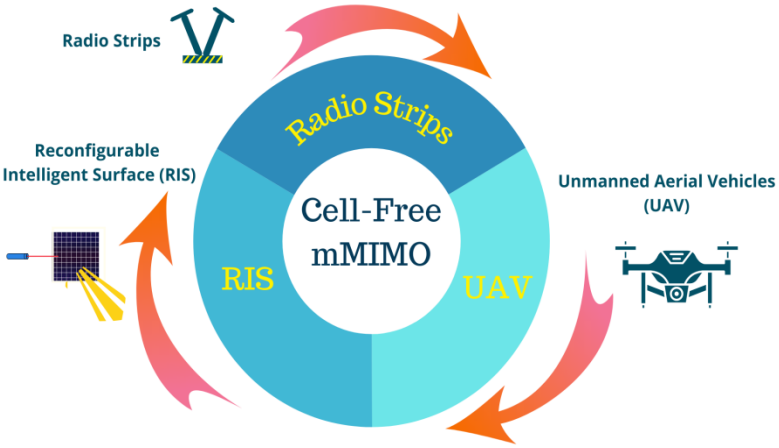
which along with quantum computing and quantum sensing offers a plethora of new applications. Quantum communication systems are engineering marvels, given that the reliable transmission of quantum information frequently entails the transit of individual light particles, or photons, through a universe flooded with trillions upon trillions of photons. In order to leverage the potential for cryptographic security afforded by the laws of quantum mechanics, emerging commercial quantum communication networks seek to provide a technological substitute for current public-key encryption protocols, which are currently vulnerable to the threat posed by future quantum computing systems [18]. Quantum communication is the part of 6G enabling technologies.

Cell-Free Massive Multiple-Input Multiple-Output

Cell-Free Massive Multiple Input Multiple Output (CF mMIMO) systems are made up of several dispersed, inexpensive, and antennae for low-power access points that are linked to a controller of network. There are a lot more antennas than massive MIMO. All access point antennas serve every user concurrently, and the system is not divided into different cells. In CF mMIMO, a central processing unit is linked to numerous dispersed access points, which serves fewer users across the resources of same time-frequency domain. In comparison to co-located mMIMO and traditional system with small-cell, the technology has demonstrated a great deal of promise for enhancing network performance from a variety of angles. Additionally, the system may be easily combined with a range of cutting-edge methods and technologies for network beyond 5G, enhancing network performance from multiple angles. Even though CF mMIMO systems have shown significant theoretical benefits, it is still unclear how exactly the system would be deployed in a scalable, real-world setting. The paper [19] gives a thorough overview of the CF mMIMO system, covering a wide range of topics from the system's fundamental model to its intricate operation, its practical implementation constraints, and its potential for integration with cutting-edge methods and technologies. Fig **4** shows collaboration of CF mMIMO with Reconfigurable Intelligent Surfaces (RIS), radio strips, and unmanned aerial vehicle (UAV).

Fig 4. Cell-Free massive MIMO in collaboration with reconfigurable intelligent surfaces (RIS), radio strips and unmanned aerial vehicle (UAV).

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Visible Light Communication

The frequency range in which VLC operates is 400–800 THz. Unlike RF methods in the lessen THz range that rely on antennas, VLC implements the transceivers using sources of illumination, particularly light-emitting diodes (LEDs), as well as arrays of photodiodes or image sensors. These transceivers make it simple to attain a large bandwidth at low power consumption (100 mW for 100 Mbps) without producing radio or electromagnetic disruption [20]. Because standard LEDs have a long lifespan (up to ten years), are inexpensive, and have unrestricted access to spectrum, VLC is a desirable option for use cases where battery life and price of access are important considerations, like vast IoT and wireless sensor networks (WSN) [21]–[24].

Digital Twin

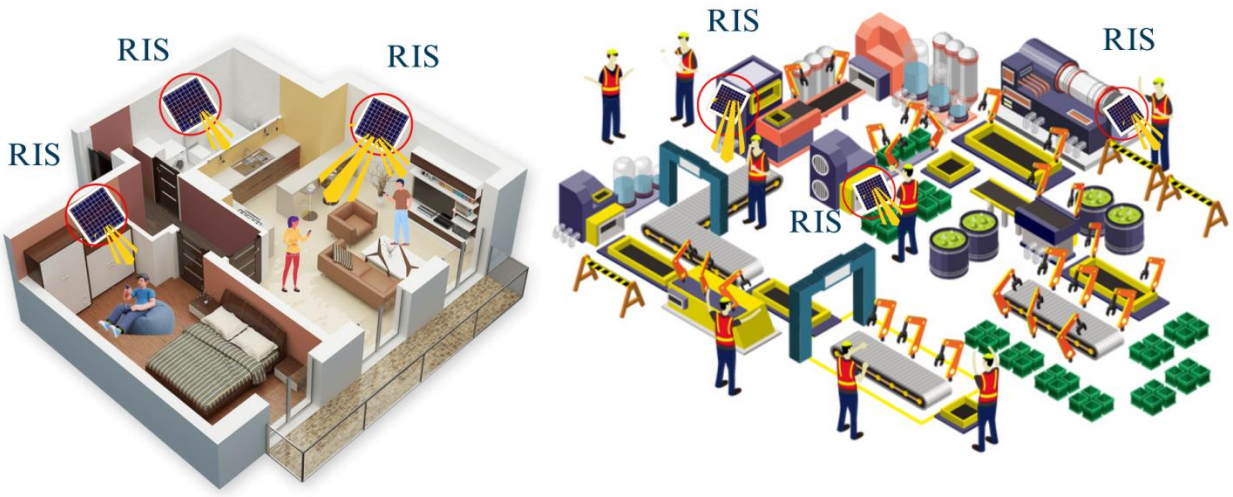
Digital twins are a new technology and a major application for the 6G communication infrastructure. It speaks of the logical duplicate of a physical thing, often known as a virtual object or software replica [25]. All of the dynamics, traits, essential elements, and significant attributes of an actual physical thing that functions and endures all the way through its life cycle must be reflected in the virtual form [26], [27]. The life span of a physical twin is being followed by the digital twin. As a result, the procedures for maintaining, predicting, managing, and optimizing it begin and terminate in tandem with the corresponding physical twin. By means of a special key, every digital twin is connected to its corresponding physical twin. A one-to-one connection exists between the digital and physical counterparts can be established with the use of the unique or specialise key, which is also utilised to identify the physical twin. The digital twin has gained a lot of attention recently from the manufacturing, research and development, industry 4.0, and other sectors due to its significance in applying AI methods to raise the calibre of goods, services, machinery, devices, etc. in a certain situation.

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Reconfigurable Intelligent Surfaces (RIS)

By adjusting the surface's electric and magnetic characteristics, a programmable surface structure known as a RIS can be utilised to regulate the reflection of electromagnetic (EM) waves. An essential technology for supporting 6G wireless communication networks is RIS. It entails fine-tuning radio wave reflection and scattering utilising tiny components like antennas and sensors to increase signal strength and energy efficiency. RIS design (material, for example), RIS control algorithms, RIS channel modelling, RIS integration with other network components, etc. are some of the study areas of interest in RIS [24], [25] The
Fig 5 shows the example for use of RIS in different scenarios. a) provides use of RIS at home and b) gives information about its use in industry.

Fig 5. Illustration for the use of RIS in different scenarios a) Home b) Industries



Requirements

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Systems using 5G new radio (5G-NR) are now available for purchase. The goal of 3G Partnership Project (3GPP) versions 16 and 17 is to capture the interworking capabilities of massive machine-type communication (mMTC), enhanced mobile broadband (eMBB), and ultra-reliable low-latency communication (URLLC) in order to facilitate the emergence of 5G-NR. However, potential work has been done in order to facilitate 6G in the society. There are certain requirements for 6G system mention in the Table 1 [30], [31]. Here in the Table 1 key performance indicator (KPI) are operating bandwidth, carrier bandwidth, peak data rate, user experience rate, connection density, user plane latency, control plane latency, mobility, and reliability.

Challenges under 6G

There are certain challenges in implementing 6G communication system [30] such as,

Leveraging Bandwidth at Sub terahertz Frequencies

Implicit expectations of significantly larger bandwidths compared to 5G are brought about by the idea that carrier frequencies will rise towards sub terahertz bands. The most realistically possible choice for the next ten years appears to be operating the system within the first frequency window, or W1, taking into account the atmospheric absorption curve at sea level as a function of frequency. Although this introduces substantially wider bandwidths, it is nearly impossible to realise radio receivers using the entire bandwidth. This is especially true if one wishes to keep the RF front end's gain and phase homogeneity. The maximum carrier bandwidth of 5G-NR systems operating in the mm Wave frequencies is 400 MHz. Similarly, 1-GHz bandwidth-limited close proximity services at sub terahertz bands are currently under discussion [32]. The significant test for sub terahertz frequencies is because of the increasing impacts of phase noise, regardless of the size and construction of the antenna array. As a result, the ability to maintain RF front-end linearity and antenna-coupled RF circuits will be balanced against the requirement to satisfy isotropic radiated power constraints for the secure function to figure out the optimum number of carriers and optimum operable bandwidth. This will provide a significant scientific problem in the decades to come.

Extending Semiconductor Technologies' Boundaries

Current sub-10-nm CMOS technology and upcoming innovations utilising extraordinarily fast logic transistors at lower supply voltages and costs are needed for digital processing. In analogue design, robustness to process and temperature fluctuations, robustness to noise, quality of on-chip components, consistent output signal power, and a sufficiently high frequency are required.

Table 1. 6G system requirements that are anticipated as well as a comparison of 6G performance metrics with 5G

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systems

Key Performance Indicator	6G	5G-NR
Operating bandwidth	Up to 400 *MHz* for sub-6G-Hz bands	Upto 400 *MHz* for sub-6G-Hz bands
Carrier bandwidth	$\geq$ 400 *MHz*	400 *MHz*
Peak data rate	$\geq$ 1 *Tb/s* (holographic and immersive applications)	20 *Gb/s*
User experience rate	1 *GB/s*	100 *Mb/s*
Connection density	$10^7\ devices/Km^2$	$10^2 devices/km^2$(mMTC)
User plane latency	10 μs to 1 *ms*	4 *ms*
Control plane latency	$\leq$ 20 *ms*	20 *ms*
Mobility	1000 *km/h*	500 *km/h*
Reliability	Up to 10^{-7}	10^{-5} ultra reliability low latency communication (URLLC)

Sub terahertz Frequency Integrated Transceiver Design

A transceiver architecture for cellular systems usually consists of a receiver with a low-noise amplifier (LNA), a local oscillator (LO) sequence with frequency multipliers, and an I/Q mixer. The architecture of the transmitter is similar, with the PA coming after the mixer. Subterahertz frequencies may significantly reduce the possible receiver noise figure and transmitter efficiency in comparison to lower ones [30].

Realistic Terabit/Second Rate Attainment

Large antenna arrays never seen before will be needed for operation in the 140–350 GHz frequency range. The creation of RF feed networks that enable gigahertz-wide bandwidths presents basic issues is to create such arrays that function with great radiation potential. While a large number of elements will end up resulting in narrower beam widths in the overall setting of phased arrays, as the bandwidth is improved up, the array performance at both the end edges of the band will change significantly. The outcome of this is deviation of radiation pattern of the main-lobe and an increase in sidelobe power are the outcomes of this.

Accomplishment of Worldwide Sub-millisecond Latency

The KPI indicator with respect to 5G and 6G in terms of latency is given in Table 1. It is a difficult task to achieve such kind of latency beyond 5G.

Conclusion and future prospects

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The drivers, specifications, initiatives, and facilitators for 6G mobile system's future generation were all thoroughly covered in this article. In light of the intense desire that both academics and industry have for creating 6G, it is likely that 5G won't be the end of the evolution of a new generation. Instead, the first 6G network is anticipated to be deployed in 2030 or even before. The 6G system needs to meet extremely rigorous standards on latency, reliability, flexibility, and safety in addition to offering a large increase in peak data rate, coverage, system capacity, user experience rate, and connectivity density. KPIs will therefore usually be ten to hundred times better than those of the 5G system. The researcher can work and experiment with new technologies, apps, and services that could support or enhance 6G in addition to investigating the possibilities and potential of 6G. It's crucial to interact with the wireless community by offering the thoughts, comments, and suggestions on 6G. Researchers and industrialist should take part in the conversations, arguments, and teamwork that could shape the future course and architecture of 6G. The whole world will be digitally connected by 6G.

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ENGINEERING PROSPECTS OF NATURAL FIBER REINFORCED COMPOSITES: A REVIEW

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Abstract

Environmental concern and sustainability issues has witnessed significant advancements in green technology in the field of material science which results in development of biocomposites in this century. Application and disposal of conventional composite structures considered critically due to the demands of legislative authorities and increasing environmental consciousness. Current developments in biocomposite science has tremendous potential for creating superior materials based on renewable resources to promote global sustainability. Biocomposites are the biodegradable materials made up with matrix and reinforcement phases. This study addresses the different materials utilized for manufacturing of biocomposites. Biocomposites are the most favorable materials because they have comparable mechanical properties with very low density and these properties can be easily tailored based on selective design application. Biocomposites have numerous advantages over conventional materials at the same time they have some challenges. These challenges and their remedies have been addressed in this article. A comparison of different manufacturing processes and characterization techniques is included. Natural fiber reinforced polymer composites have wide area of applications.

Keywords

Biocomposites, Natural Fibers, Mechanical Properties, Characterization, Manufacturing.

Introduction

A composite is an engineering material which is composed of two components, reinforcement and matrix. Reinforcement is a discrete phase while the matrix is a continuous phase. A composite can be manufactured using synthetic or natural fibers reinforced in natural or synthetic matrix. Natural fiber reinforced with natural matrix is known as a bio-composite or a natural fiber reinforced composite (NFRC). Natural fibers have numerous benefits like low density, cost effectiveness, abundance, renewability and biodegradability over synthetic fibers. Along with these advantages they possess mechanical, morphological and thermal properties comparable to that of synthetic fibers. For the creation of bio-composites, natural fibers including kenaf, flax sisal, jute, banana, and rice husk are employed as reinforcement in the polymers. If both the polymer and the fiber in a bio-composites come from plants or biodegradable materials, the composites are entirely green; however, if only one of the polymer or fibers is biodegradable or comes from a natural plant, the

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composites are only partially green. Natural fibers provide favourable economic, low density, strong specific strength, and biodegradability characteristics. Bio composites are appropriate for light-weight applications, packaging, disposable consumer products, and sensitive consumer goods.

This study provides a brief overview of the various materials, contemporary research and development activities, as well as the characterization and use of bio-composites. It contains a succinct explanation of the various manufacturing processes based on the kinds of natural fibers and polymers, as well as their geometrical and mechanical characteristics. There is also a brief discussion of the characterization of bio-composites using destructive and non-destructive testing techniques. Bio-composites have demonstrated significant potential in the design of agricultural machinery, cabinets and cosines for various electrical and electronic devices, packaging, and other products.

Natural Fibers and Their Types

Fiber materials used for manufacturing composites may be synthetic or natural fibers. Synthetic fibers like carbon fibers are used because they offer very good mechanical properties. But beside their advantages there are certain problems associated with them such as high density, high cost, non-biodegradable and high carbon footprints etc. To overcome these problems, natural fibers are being used as they have comparable mechanical properties to the synthetic fibers along with low density, low cost, biodegradable and almost no carbon footprints. Figure (1) shows various natural fibers which can be used to produce composite materials [1]. Classification of natural fibers, on the basis of their origin, can be as plant based, animal based and minerals. Animal fibers (hair, silk, wool, etc.) are mainly composed of proteins while plant-based fibers contain mostly cellulose. Leaf, seed, bast, wood, grass, and stalk make up plant fibers. As reinforcement for biocomposites, minerals like asbestos, ceramic and metal are employed.

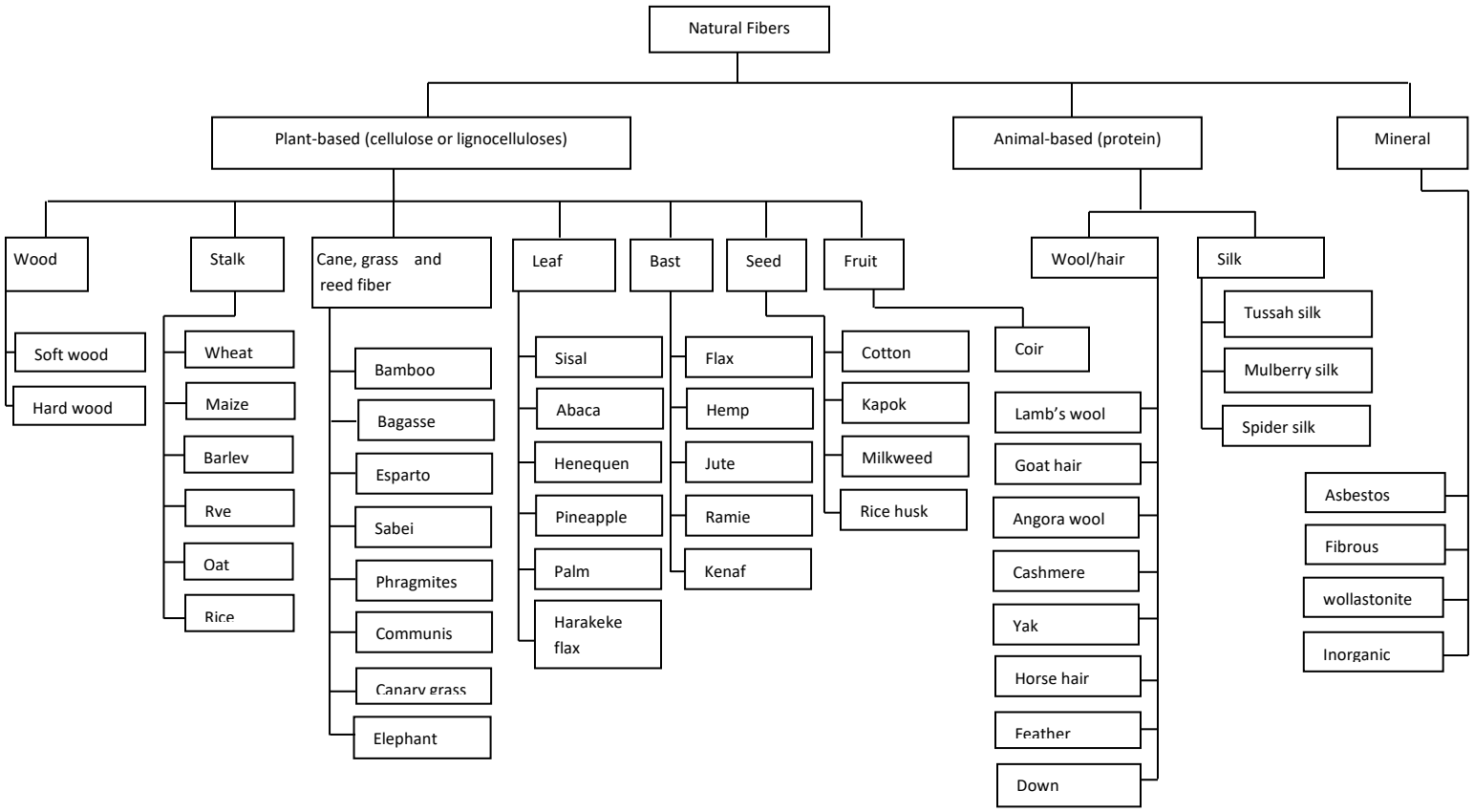
Since they comprise at least one component (such as reinforcement or matrix) made from easily accessible renewable resources, natural fiber reinforced composites (NFRC) are considered as bio-composite materials. Nowadays, different industries like aerospace, military, marine and building engineering are using NFRC's to build structural components. Manufacturing these materials has attracted interest from several engineering and structural sectors due to the potential for weight reduction and improved product efficiency. In addition, using natural fibers as reinforcing material rather than synthetic fibers has a number of technological, financial, and environmental advantages [2]. Although natural fibers are employed, due to their ecological advantages, in household soundproofing applications, construction applications and automotive, their mechanical properties are low.

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Figure 1: Types of natural fibers



Properties of natural fiber

Physical Properties

The natural fiber's physical characteristics are its diameter, length and density. As shown in table 1, these are different for different types of fiber.

Diameter of fiber obtained from same plant can vary with its location on plant i.e. top, middle, and bottom part of flax stems. The mean diameter of fiber was found decreasing from bottom to top of the stem [3]. J.B. Sajin et.al. studied the effect of fiber length of alkali treated jute fiber (ATJF) on the flexural, tensile, impact strengths and hardness of ATJF reinforced isopthalic polyester(IP) composite. Five samples of composite were prepared using different gauge i.e. 5, 10, 15, 20 and 25 mm of fiber lengths. The results reveals that an increase in fiber length, increases the mechanical properties of ATJF reinforced IP composite. The largest value of tensile strength, flexural strength,

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tensile modulus, flexural modulus, impact strength and hardness were recorded as 50.26 MPa, 57.689 MPa, 2.3 GPa, 2.8 GPa, 8.320 J/cm^2, 97 HRRW respectively. The maximum values were observed for a fiber length of 20mm [4] .

Table1: Physical properties of natural fiber [2] [5]

Natural fiber	Length(mm)	Diameter(µm)	Density(kg/m^3)
Banana	30	13.76	1325
Hemp	11.2	19.9	1200
Flax	31.75	20	1450
Abaca	4.9	18.2	1500
Alfa	2.5	5-10	890
Bagasse	1.7	20	900
Bamboo	2	25	1500
Coir	1.25	17.5	1250
Cotton	42	14.5	1550
Curaua	-	170	1400
Isora	-	10-20	1200
Jute	2.55	18.4	1400
Kapok	20	25	3.84
kenaf	2.35	19.8	1300
Pineapple	-	50	1540
Ramie	160	31.55	1550
Sisal	2.5	21	1400
Rice Straw	0.6-1.3	5-14	860-870

Chemical Properties

The natural fibrils can be used as crucial design cues for compound composites that are positioned spirally since they are formed of cellulose suspended with formless lignin and polyose matrix. Table No. 2 lists the different chemical compositions, including cellulose, hemicellulose, moisture content, lignin, ash, pectin, and wax. The location of plant tissue and the rate of growth affects the chemical composition of fiber.

Although they have all the components required for bonding with polymer matrix, they also contains non-cellulosic constituents, such as hemicellulose, pectin, waxes and lignin which lessen the bonding nature of the material. Some pre-treatment techniques had additional regulated elements installed in order to get rid of that. Some of the experimental works are presented in this context based on the non-cellulosic contents removal.

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Table 2: Chemical composition of various lignocellolosic fibers [2][5]

Natural fiber	Cellulose(%)	Hemi-cellulose(%)	Lignin(%)	Pectin(%)	Waxes(%)
Banana	62.4	12.5	7.5	4	-
Hemp	81	20	4	.9	.8
Flax	70.5	16.5	2.5	.9	-
Abaca	62.5	21	12	.8	3
Alfa	45.4	38.5	14.9	-	2.0
Bagasse	37	21	22	10	-
Bamboo	34.5	20.5	26	-	-
Coir	46	0.3	45	4	-
Cotton	89	4	.75	6	0.6
Curaua	73.6	5	7.5	4	-
Isora	74	-	23	-	-
Jute	67	16	9	0.2	0.4
Kapok	13.16	-	-	-	-
Kenaf	53.5	21	17	2	-
Pineapple	80.5	17.5	8.3	4	-
Ramie	72	14	0.8	1.95	-
Sisal	60	11.5	8	1.2	-
Rice Straw	32-47	19-27	5-26	-	

Ujendra Kumar et al. [6] found that 5% NaOH treated banana fiber followed by washing under tap water and dried at 90°C in a hot air oven shows improvement in mechanical properties and thermal stability. Seyoum Getaneh Abebayehu et al. [7] used 10% of NaOH at 200 rpm stirring speed of for 2h at 90°C for the treatment of Sisal fiber to decrease its hydrophilic behavior and thus improving its compatibility with polypropylene. T. Dinesh et al. [8] treated pineapple fiber and nano-silica particle with APTES(3-Aminopropyltriethoxysilane) using aqueous solution method. They concluded that adding 30% silane surface modified pineapple fiber improved flexural, tensile and impact toughness at higher level. Tabassum Sadik et al. [9] treated Date Palm Fronds (DPF) fiber and Coir fibers with 5% and 10% NaOH solution. Their results depicts that 30% wt coir and DPF fiber treated with 5% and 10% of NaOH solution respectively, shows highest strength to weight ratio. M. Asim et al. [10] Studied effects of Silane treatment on Kenaf Fiber (KF) and Pineapple Leaf Fiber (PALF) reinforced phenolic hybrid composite. PALF and KF fibers were treated with 2% silane solution for 3 hours followed by washing and drying in oven at 80°C 48 h. Energy absorption, flexural strength, impact strength and flexural modulus increases with increase in treated PALF content while tensile strength and modulus increases with treated KF.

Sanjay et al. [11] state that thermal behavior, degree of inflammation and crystalline alignment of natural fiber is affected by the amount of moisture contained in it. The highest cellulose content

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treated fiber has higher cellulose values, which is a well-known fact. Additionally, the interfacial adhesion is improved between unidirectional and the remaining fibers since acrylic acid treated fibers have wax concentrations of 0.13 wt% which is lower than other fibers. Similarly, observations of studies of Chirayi et. al. [12] show a considerable decrease in the amount of ash and wax, which increases thermal stability by serving as a fire-retardant and preventing the reaction of chemical groups with sensitivity.

Mechanical Properties

For structural applications of natural fiber reinforced composites, mechanical properties are important parameters. Determination of reinforcement for the polymer composites is based on careful consideration of mechanical properties of natural fibers. Table 3 shows different natural fibers with their mechanical properties. Tensile strength, flexural strength, impact strength, tensile modulus, flexural modulus, % elongation, hardness, and other parameters must be taken into consideration for a variety of biocomposites applications.

High cellulose content in reinforcement is desirable to get high mechanical and thermal properties. To improve the mechanical strength, surface treatment can be used which reduces hemicellulose and lignin type non-cellulosic components and thus enhance the cellulose content. Also, modification of the fiber's surface increases its hydrophobic properties by reducing its hydrophilic nature.

Table3 : Mechanical Properties of Natural Fibers [13][14][5]

Fiber	Elongation (%)	Tensile Strength (MPa)	Young's Modulus (GPa)
Carbon	1.4-1.8	4000	230-240
E-Glass	0.5	2000-3500	70
S-Glass	2.8	4570	86
ARAMID	3.3-3.7	3000-3150	63-67
Cotton	7-8	287-597	5.5-12.6
Jute	1.5-1.8	393-773	26.5
Flax	2.7-3.2	500-1500	27.6
Hemp	2-4	690	70
Ramie	3.6-3.8	400-938	61.4-128
Sisal	2-2.5	511-635	9.4-22
Coir	30	175	1.27-6
Kenaf	1.6	930	53
Banana	3	529	914
Pineapple	2.4	170-1627	60-82

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Bagasse	6.20-8.2	257-290	15-18
Rice Straw	2.11-2.25	435-450	24.67-26.33

Thermal Properties

In the area of material science, thermal investigation is a significant experimental characterization method. Thermal properties of synthetic polymers and biomaterials having various phases and morphologies can be analyzed using thermal characterization. Thermo-gravimetric analysis, differential thermal analysis, differential scanning calorimetry, thermo-mechanical analysis, and dynamic mechanical analysis are some of the traditional methods for thermal analysis. To prevent catastrophic failure in applications at elevated temperatures, it was required to analyses the thermal characteristics of the composite before reinforcing the natural fiber in the polymer composites.

Manufacturing Methods

The natural fiber composite processing is influenced by some principal parameters like fiber volume fraction, moisture, fiber type, chemical composition and aspect ratio. Composites are made using various variables, such as the final product design, material type, fiber, polymer resin, and particle sizes, material temperature, durability, and part complexity. Polymer industries, for manufacturing high-quality composite parts need to develop less expensive fabrication techniques. Enhancement of fiber volume fraction in composite causes an improvement in strength, stiffness and hydrophobicity of the composite while decreases the strain rate. Natural fibers have a limitation of processing temperature. They are required to be processed below the temperature of 200° C to avoid degradation of cell wall. When the processing temperature of natural fiber is above this temperature limit, NFRC may shrink, degrade, and become low in strength and durability. This may be due to oxidation, depolymerization, decarboxylation, hydrolysis, recrystallization, dehydration, and other physiochemical process. Various methods are used for manufacturing of natural fiber composites. Some common manufacturing techniques include pultrusion, hand layup, sheet molding, compression molding, injection molding, filament winding, vacuum infusion and cold pressing, which largely depend upon the materials being used.

Pultrusion

The word pultrusion is created by fusing the phrases pull and extrusion. Similar to extrusion, pultrusion produces a product by pulling the materials through the die as opposed to pushing them through like in extrusion. A puller is used to draw continuous fiber rovings or tapes into a resin solution that contains a thermosetting polymer. Unsaturated polyester and epoxy are two most commonly used thermosetting polymers used in this process. Impregnated fiber composites, after emerging from resin bath, are dragged through a series of shaping dies. Any shape that matches the cross-section of the dies can be used for the final product, whether it be round, rectangular, square, or another shape. Additionally, one of the dies is used to cure the composite. Typically,

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the final products take the shape of rods and bars. The products are trimmed to the necessary lengths following the pultrusion process.

Fairuz et. al. [15] presented their research on rods created using pultrusion process with vinyl ester polymer reinforced with kenaf fiber. Three separate characteristics were examined in this investigation, namely fiber loadings, temperatures and speeds. Taguchi's experimental design was used to decide the number of trials needed. By controlling temperature and filler loading, three distinct speeds were used for producing rod-shaped specimens. The same is then repeated by varying the parameters, temperatures and filler loadings. For each parameter, the tensile, impact and flexural strength of NFRC rod specimens were examined.

Hand layup

It is an open mold process of composite manufacturing, in which alternate layers of fiber and matrix are laid down in an open mold. A roller is used to apply pressure for removing the air trapped into layups. It also helps in uniform distribution of fiber and matrix. In the form of molding platform silica rubber mold can be used. For easy removal of composites from the mold plate a rough coat of wax is used on it. The nano-silica particle after surface modification along with epoxy-mahua matrix was then poured into the mold and allowed to fill completely [8]. As the resin mixing, laminate quality and laminate resin concentrations are significantly depend on the expertise of operator. So it is a labor extensive technique [16].

Spray layup

Another form of open mold procedure that is thought to be an advanced form of the hand lay-up technique is the spray lay-up technique. This technique uses a spray gun to apply pressurized resin and reinforcement in the form of chopped fibers. Glass roving is frequently used as reinforcement and is first chopped using a chopper gun before being sprayed. It is possible to spray the reinforcement and matrix material simultaneously or one at a time. Spray release gel is used on the mold walls for easy removal of components from the molds. To release any trapped air in the lay-ups, a roller is rolled over the material that has been sprayed. Once the correct thickness of the product is achieved by spraying the fiber and resin, it is then either heated to room temperature or heated to a higher temperature for curing. After curing, the produced composite, object is taken out of the mold and processed further. The curing time is determined by the type of polymer used. This method gives composite materials a high volume fraction of reinforcement.

Due to of its low thermal resistance and inherent rigidity, compression-molded thermoplastic acrylic cannot meet bath tub requirements. To support the thermoplastic tub, high performance layers, glass fiber reinforced polymer (GFRP) layers, and thermosetting plastic are used. The spray

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layup method, which is believed to have a high level of business efficiency, is typically used for backing up [17].

Injection Molding

The production of thermoplastics and thermoplastic-based composite products can often be accomplished using a standard injection molding machine. Natural fibers absorb moisture from the air because they are hydrophilic. First, depending on the situation, the fiber is dried using various techniques (dehumidification dryer, circulation dryer and hot air oven). The polymer and chopped short fibers are either pre-compounding or put directly to injection molding machine's hopper during the injection molding process. For combining the ingredients, many studies advocate utilizing an extrusion machine (single or twin screw) in order to produce a proper dispersion of fibers throughout the composites [18]. Fibers must pass from the hopper to the nozzle during injection molding, when significant fiber damage may occur owing to heating and shearing action. To get over this kind of issue, researchers suggest installing a separate hopper near the nozzle (for feeding the natural fiber).

Fiber and matrix behavior (physical, chemical, and thermal properties) are completely dissimilar from one another. It's possible that the operational parameters chosen for reinforcement won't work for the matrix or vice versa. To create composite parts with remarkable qualities, it is therefore essential to have a thorough understanding of how the performance and quality of the composite is influenced by various processing parameters. These parameters must be optimized in order to cut cycle time and operating costs, which boosts production [19].

Compression Molding

One of the earliest methods of producing materials is compression molding. It is also known as matched die molding and was one of the firstly used industrial processes for plastics. Thermoset resin is heated under high pressure inside a sealed mold until epoxy resin get cured due to a chemical reaction that cross-links polymeric chains. When resin put under pressure, it flows and liquefies and takes the shape of the mold cavity before hardening to create the desired part or product. The cycle is finished when the part is sufficiently chilled and sturdy. Nevertheless, the curing process continues when the material cools to room temperature. Dialyl phthalate (also known as "allyls"), polyester, vinyl ester, phenolic (also known as phenol-formaldehyde), urea-formaldehyde, melamine-formaldehydesilicone and other rubbers and elastomers are examples of common resins [20].

High volume composite component production is done using this technology. The most often used compounds in thermosetting molding are BMC (bulk molding compound) and SMC (sheet molding compound) [21]. The main application of glass mat thermoplastics as thermoplastic polymers is as a molding compound. In a hot press both temperature and pressure are utilized while in a cold press only pressure is used after the mold cavity is filled with molding components.

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Curing happens at ambient temperature in cold compression molding opposite to hot press molding which transfers heat from the mold to the composites.

Filament Winding

Filament winding is used to create typically circular in shaped components. This is an open mold method in which a revolving mandrel serves as the mold. In this procedure, a puller draws continuous fiber rovings through a resin bath. Each preimpregnated composite is coiled around the revolving mandrel in turn. The composites are also traversed in the x direction to provide a homogeneous distribution of the composites over the length of the mandrel. Hoop, helical, and polar windings are three different types of patterns that can be used to wind a filament. This process is applied for the controlled fiber orientation and high fiber volume fraction.

Misri et al. [22] designed and tested the mechanical properties of hollow shafts constructed with kenaf fiber reinforced with unsaturated polyester composite. The preimpregnated fiber composites were dragged through a drum-style resin bath in continuous kenaf fiber rovings before being wound around a hollow rotating mandrel constructed of aluminum. They investigated the composites' tensile and torsion characteristics, for example, and contrasted their findings with those of the FEA. There is a fundamental difficulty in producing consistently smooth shaft surfaces for filament wound kenaf fiber composites. It necessitates secondary processing, such as milling.

Problems associated in Processing of NFRC

For NFRCs, achieving mechanical and functional qualities depends on a number of important parameters, including the dilation of fibers within the matrix, the size and composition of the fibers to create the matrix-fiber interface, desired strengthening effect and faults such as porosity [23]. Particularly, NFRCs are greatly affected by the amount of fiber and its characteristics like its aspect ratio (L/D), and concentration. The inherent characteristics of natural fibers are the main causes of the processing issues with NFRCs. The following essential processing issues are covered: fiber hydrophilicity, machining, thermal stability of the fiber, low strength fibers that are susceptible to damage or breakage, absorption of moisture and dispersion of fiber in the matrix [24].

Hydrophilicity

The natural fiber’s incompatibility with polymer matrix and their hydrophilic nature are the main obstacles for natural fiber composites to be manufactured at large-scale. This occurs because of the high moisture absorbing hydroxyl group of natural fiber and the hydrophobic polymer matrix are incompatible. Mechanical and thermal properties decline as a result of this [7]. To increase the matrix-fiber wettability in NFRC and provide the desired mechanical properties, the compatibilizers or coupling agents must be used to treat fibers or the matrix phase. Popular fiber treatments include acetylation, alkali treatment (mercerization), plasma irradiation, electron beam irradiation, salinization of monomer or polymer on fiber and steam explosion [25].

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Thermal Stability

Given that the majority of natural fibers break down as the temperature rises, it is a crucial problem for NFRC processing. Lignocellulosic fibers and polymeric resin-based biocomposites are processed for up to 30 minutes at temperatures between 100°C and 230°C due to which fibers undergo chemical and physical changes that lead to degradation [26]. A few of the significant changes that take place during the process are dehydration, discoloration, re-crystallization, hydrolysis, de-carboxylation, and de-polymerization. High processing temperature of NFRC can change the mechanical properties, odor and color. The fibers with high content of crystalline cellulose can improve the strength and thermal stability.

Fiber Breaking

It is crucial to prevent fiber damage to FRP materials during production since it alters the structure's mechanical characteristics. Since the mechanical properties of FRP materials are significantly depends on the fiber. Particularly in continuous fiber reinforced composites (CFRP), the loads on the broken fiber are transmitted to the resin if some of the fiber filaments break off during manufacture. Therefore, strength is lost in that area of the composite as a result of the resin's lower mechanical characteristics [27]. In Injection Molding process fiber breaks at all stages of the process. At first step due to the combined effect of pressure and heat fibers get ruptured. Due to high shear values in the sprue nozzle and container, the tiny fibers used in NFRC injection molding may cause attrition. The natural fibers may also break due to collision among the fibrils, or between mold and the fiber [28].

Fiber Distribution in Matrix

The fiber distribution in NFRC plays an important role in imparting uniform properties in it. Any variation in fiber dispersion may cause variation in the properties of different sections of NFRC i.e. it may cause fiber rich or fiber deficient parts in the composite. Uneven fiber distribution is caused by fiber-fiber contact or tangling. This may be reduced by using different coupling agents like stearic acid and mining oil etc. Apart from this pectin and wax present in natural fiber can cause clinging of fibers, which can be removed by alkali treatment. Uniform reinforcement distribution should be used to split the fiber bundles to avoid robust NFRC. Fiber bundles may separate by mixing energy without fiber breaking [29].

Machining of NFRC's

To fabricate both simple and complicated products of biocomposites at large scale, it is necessary to assemble a number of single composite parts. This requires some secondary production techniques, such as joining and machining. Drilling, milling, turning, and other machining processes are needed to create items with natural fiber reinforcement. During machining operations, anisotropic and inhomogeneous properties of natural fiber-reinforced composites

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operate as obstacles and produce flaws such as fiber pull-out, delamination, chipping, spalling and matrix burning. Thus the strength of composite structure also decreases. Most important machining operation for the assembly of many components is drilling [30]. Factors including fiber qualities, tool geometry, depth of cut, feed rate, spindle speed, machining conditions, etc. affect the machining behaviour of bio-composites. The best–quality machined surface of bicomposites with least amount of damage can be obtained by choosing the right parametric parameter.

Applications of NFRC's:

The society's growing awareness and need for a pollution-free, sustainable and green environment has driven the material science and technology industries to produce cutting-edge, completely biodegradable and ecologically friendly commercial goods. The answer to the growing idea of greener and renewable products is fully green or biocomposite, which creates new chances and routes for both academics and businesses to produce a sustainable component. High strength, stiffness, renewability, extremely low weight and durability are critical demands for both structural and non-structural applications. To fulfill these demands green composite materials are currently receiving wider commercial acceptability [31]. Many scientists have focused their study in the field of green technology on developing lightweight, fuel-efficient automobiles as a means of reducing GHG emissions. The most important first choice for satisfying daily demand while also assuring environmental safety is biocomposites. The advantageous characteristics of biocomposites, such as their light weight and low cost, as well as their capacity to lower air pollution, benefit us. Despite their alluring qualities, natural fibers are weak and short-lived, but this can be fixed by blending a little quantity of synthetic fiber [32]. C. Zarna et.al. [33] studied the application of lignocellulosic nanofibers for 3D printing and concluded nanocellulose, due to their potentially high mechanical properties and high length to diameter (L/D) ratio are the high performance reinforcement for bioplastics. To improve mechanical properties of end- products, the natural fibers with optimized process parameters can be utilized for 3D printing applications. To improve a vehicle's overall mechanical performance and safety, four key areas need to be addressed. These are: Interior body parts, exterior body parts, light weighting of automobile and power train and chassis. As part of the global sustainability drive, switching to biobased and biodegradable plastics from current materials is strongly advocated so that environmental impact of polymers can be minimized. The performance of these eco-friendly biocomposites, particularly in vehicle exterior panels, does not match that of the current polymer composites. The cost of these green biocomposites is now far greater than that of conventional ones, and it is clear that automobile makers are attempting to find a cheap replacement for these materials. When these sustainable materials are combined in the best way possible, they can achieve the same level of performance as their forerunners at the lowest feasible cost [34] . In aerospace applications, hybrid biocomposites have proven significant potential. Insofar as environmental concerns are involved, hybrid biocomposites must inevitably replace conventional materials utilized in such applications. Research must now be directed towards creating these hybrid biocomposites with the necessary characteristics. A well-designed hybrid biocomposites can attain this mix of qualities, which is not

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possible in a single conventional material. It is clear that adding additional solid fiber or composite filler usually improves the mechanical properties overall. For hybrid biocomposites, the effect is sometimes called a positive hybrid effect [37].

Conclusion

At present, composites based on natural resources are the main focus for the researchers due to their biodegradability. Natural fiber reinforced polymers have low density, very impressive mechanical properties and amazing molding flexibility that is why they are considered as lightweight and economical materials. low. The selection of natural fibers for manufacturing of biocomposite for various structural and non-structural applications depends upon their properties. Surface treatment of fibers is a method which can be used to enhance the compatibility of hydrophobic matrix material and hydrophilic fiber. Higher chemical, mechanical, and thermal properties are present in chemically treated fibers than raw fibers. Natural fiber reinforced composites face various challenges during their processing due to their low thermal stability, hydrophilic nature of fiber, fiber breaking, non-uniform fiber distribution etc. However, these challenges can be overcome by surface treatment of fibers, by choosing proper processing technique and taking optimum length of fiber. The application spectrum of composite materials is very wide. They have been utilized in very sophisticated automobile and aerospace components very common kitchen and sports goods. To produce good quality products of natural fiber reinforced composites proper manufacturing technique should be used. Injection moulding process is suggested for producing defect free products with fast processing cycle and ease of operation. To influence the properties of composite various parameters like temperature, chemical treatment of fiber, processing method, volume fraction of fibers, stacking sequence, orientation of fibers and weave pattern can be varied. Further crop residues such as rice straw and sugarcane bagasse have great potential to be utilized as natural fibers in manufacturing of natural fiber reinforced composites.

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PROCEEDINGS OF 10IH INTERNATIONAL SYMPOSIUM ON FUSION OF SCIENCE AND TECHNOLOGY (ISFT-2024)
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PRECISION DETECTION OF AUTISM SPECTRUM DISORDER IN CHILDREN THROUGH MACHINE LEARNING MODELS

An Experimental Analysis Child, Adolescent and Adult Datasets

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Abstract

This project aims to detect Autism Spectrum Disorder (ASD) utilizing machine learning algorithms. Datasets, collaboratively collected with healthcare professionals, undergo pre processing to ensure quality and diversity. Feature selection focuses on relevant indicators for ASD. Employing various machine learning models, including Random Forest Classifier , Support vector machine and Ada Boost Classifier these are our Algorithms to be used and the project trains models with optimized parameters. Evaluation metrics such as accuracy and precision gauge model performance. Results demonstrate the effectiveness of the approach in ASD detection. The study contributes to early diagnosis, paving the way for timely intervention. Future work involves refining models and expanding the dataset for enhanced accuracy and generalizability.

Keywords

Autism Spectrum Disorder , Machine Learning , ASD detection , Prediction , Accuracy plot

Introduction

In a ground breaking evolution, Autism Spectrum Disorder (ASD) precision detection undergoes a revolutionary metamorphosis, entwined with the intricate dance of machine learning models. Advanced algorithms, akin to digital soothsayers, plumb the depths of childhood behaviour, communication, and interaction. Beyond traditional diagnostics, machine learning emerges as a beacon of precision, ling subtle patterns with unprecedented accuracy. This paradigm shift transcends mere technology; it's a profound commitment to early intervention and empathetic care for children navigating ASD's complexity. Algorithms, navigating diverse datasets, paint nuanced portraits, refining diagnoses to an art. Collaboration is key; machine learning models and healthcare professionals dance in synchronized pursuit of early detection. In the realm of machine learning, where algorithms are akin to scholarly linguists deciphering a cryptic text, the ability to discern complex patterns and unearth latent relationships becomes the hallmark of their proficiency. The algorithms, akin to poetic savants, unfurl the canvas of ASD detection with precision that surpasses the norms of conventional methodologies. This proposed symphony, orchestrated by the amalgamation of ML algorithms and accuracy, articulates a magnum opus of diagnostic prowess. We have collected 3000+ images to be collected. The tapestry woven by machine learning algorithms extends beyond the realms of conventional techniques, demonstrating a prodigious leap in diagnostic accuracy.

Autistic Images



Fig 1.1 Autistic Persons Datasets

Not Autistic Images



Fig 1.2 Non Autistic Persons Datasets

System Architecture

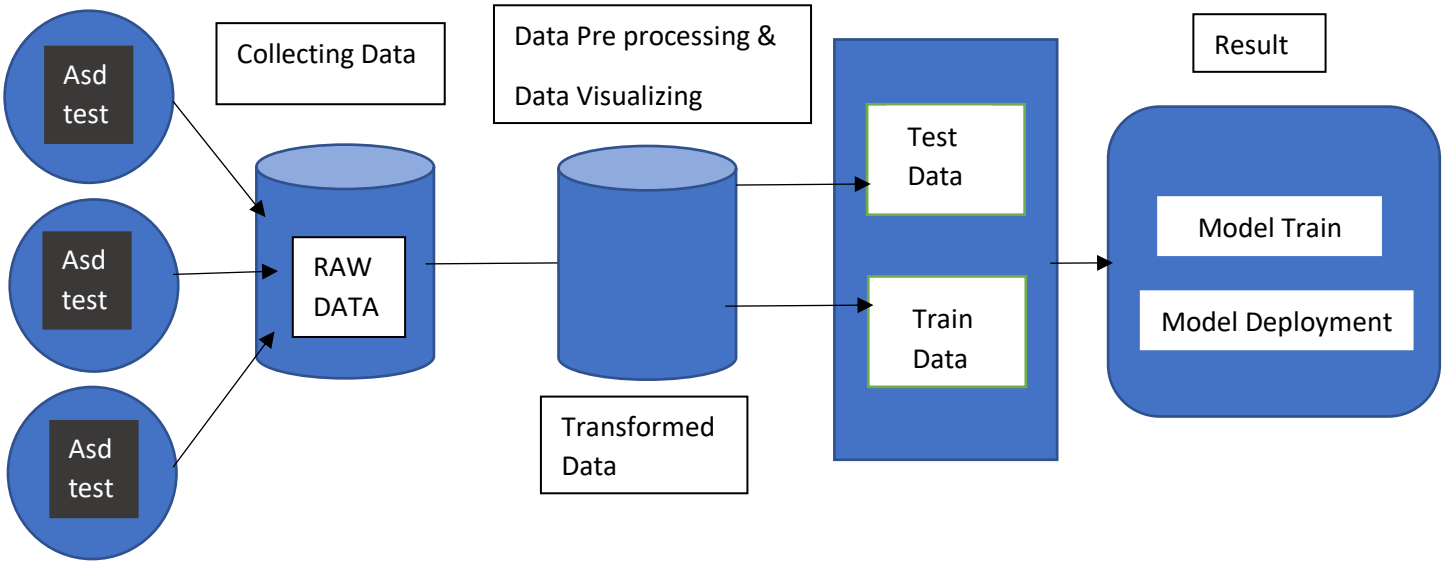


Fig 2 System Architecture

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PROCEEDINGS OF 10TH INTERNATIONAL SYMPOSIUM ON FUSION OF SCIENCE AND TECHNOLOGY (ISFT-2024)
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Methodologies

Data Collection

In the symphony of data collection, a pivotal stage unfolds—a meticulous dance assembling a diverse dataset, weaving together demographic, behavioural, and medical threads. This kaleidoscopic approach guarantees the model's adeptness in spanning ages and cultural landscapes, capturing nuanced intricacies vital for precise Autism Spectrum Disorder (ASD) detection. The opulent tapestry of the dataset assumes paramount importance, laying the groundwork for a model that transcends singular perspectives, seamlessly adapting to the multifaceted manifestations of ASD in the vibrant narratives of children's lives.

Data Pre Processing

Embarking on the intricate journey of data pre processing stands as a pivotal crossroads, overseeing the metamorphosis of raw data into a polished and manageable state. Skill fully navigating the elusive terrain of the sincere to of data gaps, employing a strategic interplay of imputation methods, custodian, safeguarding the integrity of the dataset and weaving a tapestry of completeness .Within the expansive symphony of data refinement, the limelight elegantly shifts towards the normalization and standardization of features.

This transformative act thrusts the features onto a common stage, an arena of equilibrium where they shed their diverse scales, dismantling the looming shadow of undue variable influence. In the meticulous ballet of preparation, a precision filled symphony unfurls, constructing a robust foundation resonating with the echoes of methodical artistry. This foundational ballet, intricately choreographed, not only sets the scene but constructs a durable scaffold, laying the groundwork for subsequent analyses and the flourishing evolution of models—a narrative unfolding with a rhythmic burstiness and a perplexing depth akin to the nuanced strokes of human expression.

Data Visualizing

Within the intricate domain of precision ASD detection, the omnipotence of data visualization stands as an indomitable force. The deployment of avant-garde exploratory data analysis techniques metamorphoses this stage into an unfolding visual saga, an enigmatic narrative that unfurls the latent tapestry of patterns woven within the dataset. These visual elucidations transcend mere images, morphing into tangible insights, a compass guiding the discerning travel through the labyrinthine landscapes of feature distributions, correlations, and outliers

.In this visual symphony, the discerning eye discerns the subtle hues of feature distributions, deciphers the clandestine dance of correlations, and unearths the outliers' hidden melodies. These revelations, akin to cryptic whispers, become the guiding stars in the constellation of informed decision-making, casting their luminous influence during the critical phase of feature selection. In the realm of ASD detection through machine learning, data visualization serves as a powerful tool to unravel the intricate relationships and patterns within multidimensional datasets.

Visual representations of features extracted from behavioural observations, neuroimaging scans, or genetic data provide a comprehensive overview of the information used to train models. Scatter plots, heatmaps, and box plots can effectively showcase the distribution and relationships between various features, aiding researchers in identifying potential correlations or distinctions between individuals with ASD and those without. Moreover, visualizing the decision boundaries or feature importance of machine learning models such as Support Vector Machines, AdaBoost Classifiers, or Random Forests enhances interpretability, offering insights into the factors contributing to accurate ASD classification. These visualizations not only facilitate a deeper understanding of the data but also assist in communicating findings to diverse audiences, fostering collaboration between data scientists, clinicians, and other stakeholders in the pursuit of effective ASD detection and diagnosis.

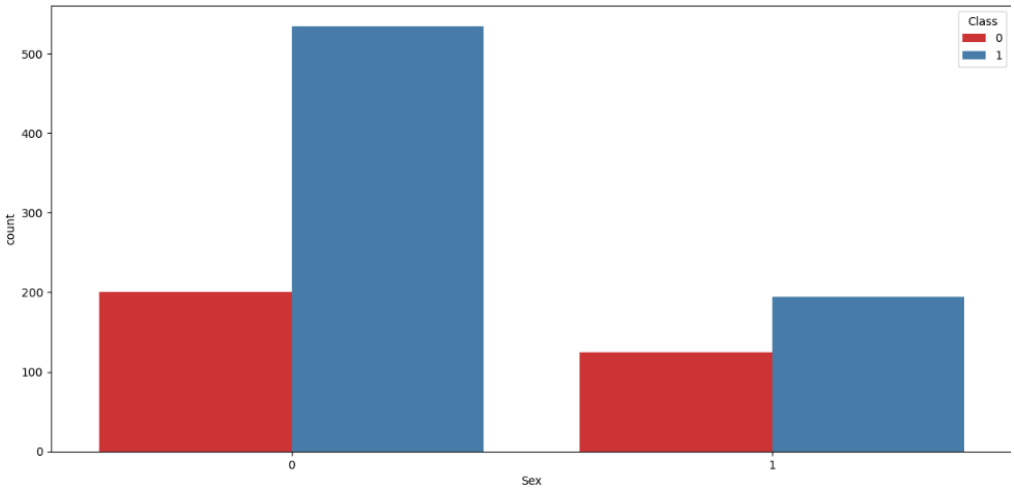
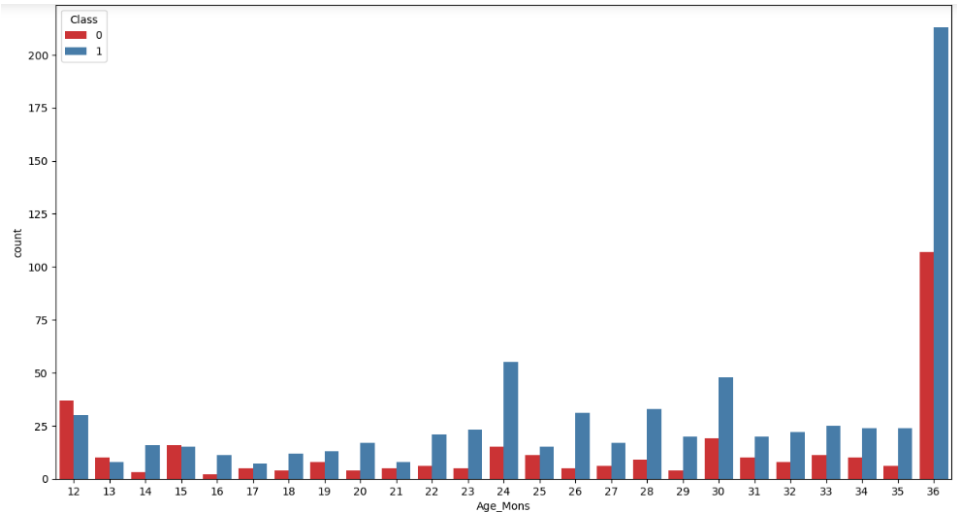


Fig 3.1 Data visualizing of male and female



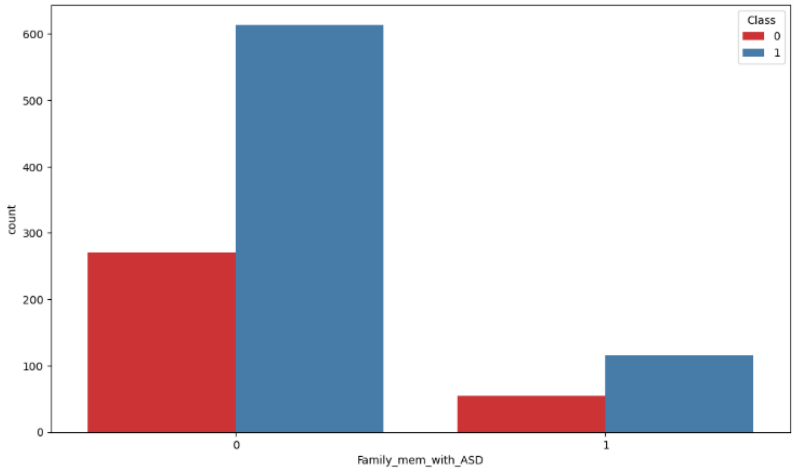


Fig 3.3 Data visualizing of Family Members

Process Diagram



Fig 4 Process Flow Diagram

In the intricate journey of precision Autism Spectrum Disorder (ASD) detection in children through machine learning models, a systematic process unfolds, enhancing accuracy at every turn. The initial stage, a tapestry of data collection, weaves together behavioural and developmental information, laying the foundation for model training. Feature extraction, a delicate brushstroke, identifies key patterns signifying ASD, refining the model's prowess to discern between typical and atypical behaviour. Enter the grand algorithms— Support Vector Machines or Neural Networks— orchestrating a symphony of classification.

Cross-validation emerges as the vigilant guardian, ensuring the model's performance stands robust, while hyperparameter tuning delicately fine-tunes the algorithm, seeking optimal harmony. Continuous refinement, akin to an ever-evolving melody, occurs through feedback loops, adapting the model to the nuances of evolving diagnostic criteria. This exhaustive process, more than a quest for accuracy, becomes a symposium contributing to the ongoing evolution of machine learning applications in healthcare—a catalyst for early intervention and support for children navigating the intricate landscape of ASD. In the precision dance of detecting Autism Spectrum Disorder (ASD) in children through machine learning, meticulousness reigns.

The initial collection of data captures the essence of crucial behavioural and developmental details, laying a solid groundwork for model training. Feature extraction delicately isolates the quintessential patterns that define ASD, enhancing the model's ability to discriminate with finesse. Machine learning algorithms, the maestros in this symphony, play the crucial role of accurate classification, harmonizing the complex notes of healthcare .Navigating the complex realm of precise ASD detection through machine learning, a careful choreography unfolds to enhance accuracy. In the initial phase, data collection forms a rich tapestry of behavioural insights, laying the groundwork for model training. Feature extraction, akin to an artist's brushstroke, reveals essential patterns in ASD, honing the model's ability to distinguish typical and atypical behaviour. The ensemble of machine learning algorithms, whether Support Vector Machines or Neural Networks, orchestrates a symphony of classification.

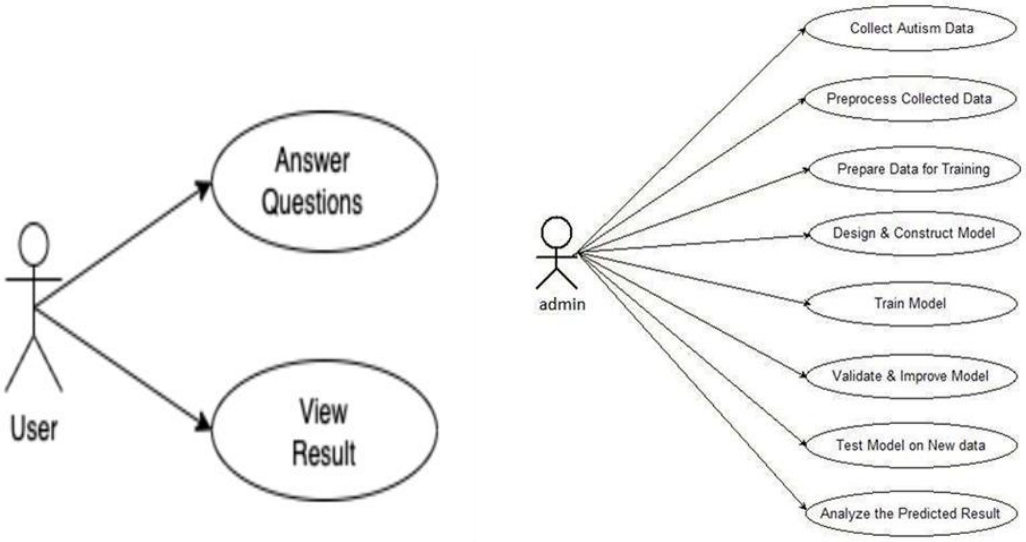


Fig 5 Use case diagram

In the intricate tapestry of precision Autism Spectrum Disorder (ASD) detection, the UML diagram unfolds as a multi-faceted composition. The Use Case diagram, a narrative maestro, outlines system functionalities, orchestrating a symphony where entities like data and algorithms dance in intricate patterns. The Class diagram, a visual ballet, paints relationships between these entities with strokes of complexity. Enter the Sequence diagram, a dynamic choreographer, capturing the ballet's essence—the pulsating interactions during the detection process. These visual representations, like avant-garde canvases, streamline the comprehension and development of the ASD detection system. Actors such as the "Clinician" and the "Machine Learning Model" take stage in this elaborate production. Additional cases, like "Update Model," add a burst of complexity for refinement, while "Provide Results" emerges as a crescendo, presenting diagnostic outcomes with a burst of insights.

In this symphony of visual abstraction, the Use Case diagram acts as the conductor, orchestrating the functionalities with a nuanced precision that resonates through the entire system. The Class diagram, an intricate ballet, weaves a tale of relationships between data and algorithms, each step a calculated move in the intricate dance of ASD detection. The Sequence diagram, a dynamic choreographer, captures the rhythm of interactions, unveiling the lively dialogue between entities. These visual masterpieces, like an evolving sonnet, not only simplify but elevate the understanding and development of the ASD detection system. With actors as protagonists and additional cases adding bursts of complexity, they transform the process into a mesmerizing performance—an avant-garde rendition that pushes the boundaries of precision in ASD detection .

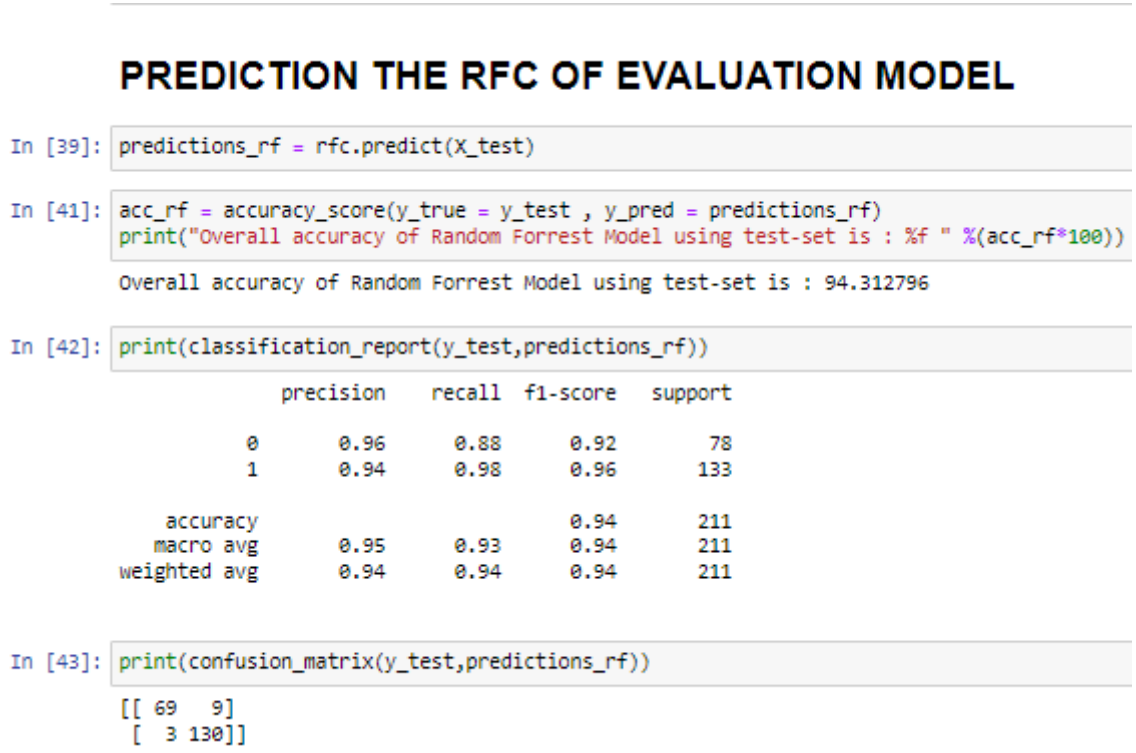
In the intricate realm of precise Autism Spectrum Disorder (ASD) detection, the UML diagram emerges as a vivid canvas, weaving together intricate elements. Picture the Use Case diagram as a storyteller, revealing the symphony of system functionalities where entities like data and algorithms engage in a dance of complexity. The Sequence diagram, a dynamic choreographer, captures the essence—the pulsating interactions during the detection process.

In this symphony of visual abstraction, the Use Case diagram orchestrates the functionalities, aligning them with nuanced precision resonating through the system. The Class diagram, an intricate ballet, spins a tale of relationships between data and algorithms, each move a calculated step in the intricate dance of ASD detection. The Sequence diagram, a dynamic choreographer, captures the rhythm of interactions, unveiling the lively dialogue between entities.These visual masterpieces, like an evolving narrative, not only simplify but elevate the understanding and development of the ASD detection system

Model Evaluation

Model training is a crucial phase in the development of machine learning models for Autism Spectrum Disorder (ASD) detection. During this stage, the selected algorithms, such as Support Vector Machines (SVM), AdaBoost Classifier (ABC), or Random Forest Classifier (RFC), learn from the provided data to make predictions. Here's a paragraph describing the model training process .In the model training phase for ASD detection, the selected machine learning algorithms, including Support Vector Machines (SVM), AdaBoost Classifiers (ABC), and Random Forest Classifiers (RFC), undergo a critical learning process.

The algorithms are fed with a carefully curated dataset comprising features extracted from various sources such as behavioural observations, neuroimaging scans, or genetic information. During training, the models iteratively adjust their internal parameters to minimize the difference between predicted and actual outcomes. Cross-validation techniques are often employed to assess the robustness of the models and ensure their generalization to new, unseen data. Tuning hyperparameters, such as regularization strength in SVM or the number of estimators in RFC, is a key aspect of optimizing model performance. This iterative learning process allows the models to capture complex patterns and relationships within the data, enabling them to make accurate predictions when presented with new cases of ASD. The success of the model hinges on the quality of the training data, thoughtful feature engineering, and careful consideration of algorithm-specific parameters to achieve a well-generalized and reliable ASD detection model.



PREDICTION THE RFC OF EVALUATION MODEL

```
In [39]: predictions_rf = rfc.predict(X_test)

In [41]: acc_rf = accuracy_score(y_true = y_test , y_pred = predictions_rf)
         print("Overall accuracy of Random Forrest Model using test-set is : %f " %(acc_rf*100))

         Overall accuracy of Random Forrest Model using test-set is : 94.312796

In [42]: print(classification_report(y_test,predictions_rf))

                       precision    recall  f1-score   support

                    0       0.96      0.88      0.92        78
                    1       0.94      0.98      0.96       133

             accuracy                           0.94       211
            macro avg       0.95      0.93      0.94       211
         weighted avg       0.94      0.94      0.94       211


In [43]: print(confusion_matrix(y_test,predictions_rf))

         [[ 69   9]
          [  3 130]]
```

Fig 6 Random Forest Classifier Accuracy

Random Forest is like the rock star of machine learning, a tool that does it all—classifying, predicting, and making sense of complex data. Picture it as a conductor leading a diverse group of decision trees, each doing its own thing independently in the vast world of training data. What gives it that special spark? A bit of unpredictability, thanks to the dance of randomness led by features and data. Think of this as a ballet of predictions where each tree, dressed in randomness, adds its own flavour to the performance Adaptability is its middle name, gracefully gliding through the challenges of scalability like a seasoned performer. Always delivering top-notch results, this algorithmic maestro is the first choice for many in the field, drawn to its rock-solid reliability.

PREDICTION THE ABC OF ADA EVALUATION MODEL

```
In [48]: prediction_ada = ada.predict(X_test)

In [49]: acc_ada = accuracy_score(y_true = y_test , y_pred = prediction_ada)
         print("Overall accuracy of ADA model using test-set is : %f"%(acc_ada*100))

         Overall accuracy of ADA model using test-set is : 100.000000

In [50]: print(classification_report(y_test,prediction_ada))

                      precision    recall  f1-score   support

                   0       1.00      1.00      1.00        78
                   1       1.00      1.00      1.00       133

            accuracy                           1.00       211
           macro avg       1.00      1.00      1.00       211
        weighted avg       1.00      1.00      1.00       211


In [51]: print(confusion_matrix(y_test,prediction_ada))

         [[ 78   0]
          [  0 133]]
```

Fig 7 Ada Boost Classifier Accuracy

AdaBoost, the maestro of ensemble learning, orchestrates a symphony of iterative brilliance, navigating the labyrinthine landscape of classification models with an unyielding quest for enhanced accuracy. Like a sagacious conductor, it assigns ethereal weights to data points, a dance influenced by their historical classification performances, creating a dynamic interplay of emphasis and de-emphasis. Each iteration, a saga of enlightenment, witnesses AdaBoost elevating the stakes for misclassified instances, compelling the algorithm to engage in an intricate ballet with the most challenging data points. It is within this pulsating rhythm that weak Precision Detection of Autism Spectrum Disorder in Children Through ML Fig. 8 Accuracy of RFC algorithm in ASD 10 learners, humble decision trees with simplicity as their forte, ascend to the stage sequentially. Their collective outputs intertwine, giving birth to a model of fortitude and accuracy, a testament to the algorithm's evolutionary prowess.

PREDICTION THE SVM EVALUATION MODEL

```
In [56]: predictions_svm = model_svm.predict(X_test)

In [58]: acc_svm = accuracy_score(y_true=y_test,y_pred = predictions_svm)
         print("Overall accuracy of SVM model using test-set is : %f"%(acc_svm*100))

         Overall accuracy of SVM model using test-set is : 79.146919

In [59]: print(classification_report(y_test,predictions_svm))

                      precision    recall  f1-score   support

                   0       1.00      0.44      0.61        78
                   1       0.75      1.00      0.86       133

            accuracy                           0.79       211
           macro avg       0.88      0.72      0.73       211
        weighted avg       0.84      0.79      0.77       211


In [60]: print(confusion_matrix(y_test,predictions_svm))

         [[ 34  44]
          [  0 133]]
```

Fig 8 Support Vector Machine Accuracy

Support Vector Machines (SVM), those formidable titans within the expansive realm of supervised learning, emerge as unparalleled entities, transcending the boundaries of classification and regression tasks with a prowess that commands attention. Their intrinsic essence delves into the relentless pursuit of pinpointing that elusive hyperplane, a mathematical frontier that, with unwavering precision, dissects the fabric of data into classes that echo with distinct clarity, all the while orchestrating a symphony of margin maximization. The heart of SVM throbs with the vitality of decision boundaries, where the hyperplane takes stage as the arbiter of classification destinies. The grandeur of this hyperplane lies not merely in its existence but in the width of the margin it carves between the realms it governs. A wider margin translates into an orchestra of generalization, an ensemble that resonates with the echoes of a model's sagacious capacity to navigate the nuances of data landscapes.

Results

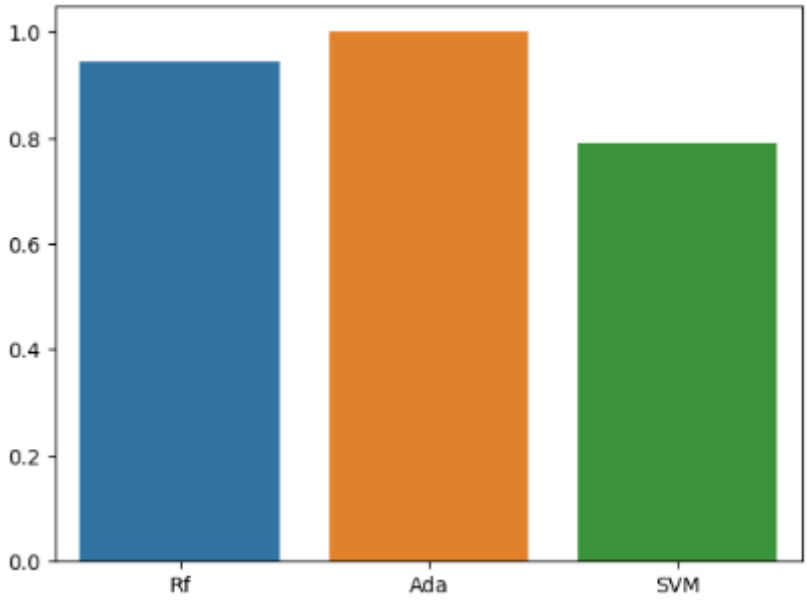


Fig 9 Final Results of Project

In this convoluted dance of computation, the AdaBoost Classifier emerges as the virtuoso, a luminary eclipsing its algorithmic counterparts with an unprecedented 100% accuracy in the arcane art of ASD detection. A feat, transcendent and spiring, that leaves the Random Forest Classifier and the venerable Support Vector Machine (SVM) trailing in its algorithmic wake. The AdaBoost, a maestro in adaptive boosting, orchestrates its ascent to supremacy by accentuating the ballet of misclassified instances in a mesmerizing symphony of successive iterations. This emphasis becomes the linchpin, the very soul of its unparalleled accuracy, affording the algorithm an unparalleled ability to refine its cognitive tapestry in the face of the bewildering complexity inherent in ASD patterns. A subtle dance with the shadows of intricacy, AdaBoost's iterative refinement unveils a tapestry of nuanced precision, rendering predictions that resonate with an almost mystical reliability.

Conclusion

In culmination, this ground breaking venture epitomizes a remarkable leap into the realms of harnessing the formidable prowess of machine learning algorithms for the intricate detection of Autism Spectrum Disorder (ASD) among the younger demographic. The discerning comparative scrutiny, manifested vividly through the kaleidoscopic representation, unequivocally situates AdaBoost at the apogee of algorithms, achieving an unparalleled zenith with a flawless 100% precision in ASD identification. This triumph stands as a resounding ode to the adaptive boosting mechanism inherent in AdaBoost, accentuating the iterative honing of feeble learners and adeptly ensnaring the labyrinthine tapestry of patterns intricately interwoven with ASD. The

expedition of this venture through the labyrinth of machine learning paradigms, encompassing the enigmatic Random Forest Classifier and the labyrinthine Support Vector Machine (SVM), bequeaths sagacious insights into their intrinsic potencies and concomitant limitations. While both the Random Forest and SVM stand as stalwart bastions of algorithmic prowess, AdaBoost unfurls itself as the quintessential choice within the delimited precincts of ASD detection, showcasing a peerless acumen, adaptive versatility, and an unassailable edge in precision. Transcending the boundaries of algorithmic discourse, the judicious utilization of Unified Model Language (UML) diagrams, notably the schematic intricacies encapsulated within the Use Case diagram, emerges as an indispensable.

The precision encapsulated in AdaBoost's discernment heralds a potential paradigm shift in the precincts of premature ASD diagnosis, paving sinuous avenues for timely interventions and a robust support system for the burgeoning cohort on the spectrum. This venture burgeons not merely as an arbiter of ASD perspicuity but as a luminary in the expansive expanse of technology-infused panaceas for diagnostics. The intersection where the vectors of machine learning and healthcare converge emanates with tantalizing promises, and this pioneering endeavour stands as a lodestar, steering forthcoming forays towards elevated denouements for children grappling with ASD and conceivably, other developmental vicissitudes.

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ADVANCED TRAFFIC MONITORING SYSTEM USING YOLOv8

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Abstract

With increasing urbanisation, growing vehicular populations, and environmental concerns, effective traffic management is essential for sustainable urban development, economic growth, public safety, and enhanced quality of life for residents. Traffic monitoring serves as the foundation for traffic management, providing the necessary real-time data and insights crucial for formulating effective strategies. Traffic monitoring involves the systematic observation, measurement, and analysis of traffic flow and patterns on roads, highways, or transportation networks. With the help of advanced technologies such as sensors, cameras, and data analytics, traffic monitoring continues to evolve, providing more comprehensive insights and solutions for managing and optimising transportation networks. This work proposes a system that utilises YOLOv8 for real-time vehicle detection, classification and counting. The developed algorithm implements the YOLOv8 for object detection and classification, ByteTrack for object tracking and Supervision library for counting vehicles in two-way directions in an efficient way. The model is tested and evaluated using a dataset video record of 30 minutes. The video is divided into small parts of 10 seconds for deep analysis and faster results. Around 12 seconds are needed to process a video of 10 seconds. Hence, it can be concluded that this model can be used for real-time application. When the automatic and manual counts were compared, the automated counting's accuracy was discovered to be roughly 94.73 percent.

Keywords: Traffic monitoring, computer vision, vehicle counting, classification, YOLOv8

Introduction

Traffic monitoring system is a system developed to collect, process and analyse data related to

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traffic conditions on roads, highways, or other transportation networks.The principal goal of such a system is to provide real-time information about traffic flow, congestion and other relevant parameters to help manage and optimise traffic patterns. These systems often use a combination of sensors, cameras, communication infrastructure, sophisticated data processing techniques and control systems enabling authorities to gather data and generate useful insights.

The imperative need for a traffic monitoring system arises from the increasing demands of rapid growth in urban population and increasing complexity of transportation networks. The traditional approach, marked by fixed traffic signals and limited data collection capabilities, fails to adapt to the dynamic nature of modern urban environments, where congestion, accidents, and fluctuating traffic patterns pose complex challenges.

Using dynamic signal timings allows efficient traffic flow and hence reduces congestion on roads [1]. The signal timing of each lane can depend on various factors like vehicle count and types of vehicles in respective lanes. Advanced traffic monitoring systems can be used in a variety of fields other than congestion mitigation, including parking lots, public safety, identification of individuals, abnormal behaviour detection, accident detection, and vehicle theft detection. Efficient traffic signal timing, facilitated by real-time data analysis from traffic monitoring systems, plays a crucial role in environmental conservation. The optimization of signal timings minimises the number of stops and starts for vehicles, leading to smoother traffic flow. By optimising traffic flow and minimising gridlock, these systems help decrease idle times for vehicles, resulting in lower fuel consumption and reduced emissions of greenhouse gases and pollutants.

Literature Review

Vehicle counting can be carried out in a number of ways, such as by utilising computer algorithms and in situ technologies. The term "in situ technologies" refers to traffic counting with detectors by the side of the road. There are various presently in use detector types including microwave radar, piezoelectric sensors, magnetic loops, and pneumatic road tubes. However, these technologies are very expensive, and their accuracy is dependent on a number of variables, including traffic volume, road type, and meteorological conditions (rain, fog, sun, and wind). Computer algorithms are a superior substitute for these techniques, as they automatically count traffic from pre-recorded video[2]. Several traditional models exist using computer algorithms to count traffic. Using the image processing technique is the fundamental process for all models. Samy S. Abu-Naser and Islam Mohammad Albatish [1] proposed an expert system that was divided into two sections: the hardware design and the Traffic Light

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Expert System (TLES). The expert system tool CLIPS was utilised to programme the TLES. To count the number of vehicles, IR sensors and an Arduino board UNO were employed in the hardware. The goal of this system is to apply a dynamic cycle time that decreases the need for human resources and traffic at junctions by raising the average number of cars passing at crossings and decreasing the amount of time drivers must wait in the lanes. With the help of OpenCV and a pre-trained YOLOv3 object detector, Mishuk Majumder and Chester Wilmot [2] provide an effective approach for automatic car counting from prepared video using TensorFlow API. The created algorithms put the YOLO paradigm for counting cars in two directions into practice.

In a system created by Cheng-Jian Lin and Jyun-Yu Jhang [3], object detection was handled by the YOLOv4-tiny model, and two models (CFNN and Vector-CFNN) that use a novel network mapping fusion technique were applied to improve classification accuracy while drastically lowering the number of model parameters. A system for counting and classifying vehicles based on computer vision was proposed by D. Shine Rajesh [4]. The Gaussian Mixture Model (GMM) background subtraction technique is used by the system to identify and count the vehicles by taking video frames. The contour areas are then compared to the presumptive values to classify the vehicles. The comparison of the two classification techniques is the work's main contribution. Both the Bag of Features (BoF) approach and Contour Comparison (CC) have been used to implement classification. An Automatic Video-Based Vehicle counting (AVVC) model was jointly developed by Nur Adilah Mohd, Salama A. Mostafa, Aida Mustapha, and Azizul Azhar Ramli [5] for precise vehicle counting from video feeds. The model uses a bilateral filter to smooth the image and remove shadows, a Gaussian distribution for background subtraction, and active contour to determine if an object is a vehicle or not. Additionally, the images' noise is reduced by the application of the Kalman Filter. In order to increase the accuracy of the counting, the Hough Transform and Histogram of Oriented Gradient (HOG) algorithms are employed in the model to enable it to distinguish between two vehicles that overlap. They offered a robust segmentation algorithm that identifies objects' foreground pixels that correspond to moving vehicles. Table 1 represents the comparison table of various techniques used by researchers for vehicle counting and classification.

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Table 1.Comparison of various techniques for vehicle counting and classification

Year	Title of the research paper	Technology used	Type of dataset used	Accuracy	Remarks
2019	Modelling and Controlling Smart Traffic Light System Using a Rule Based System	Rule Based System, sensors and Arduino UNO	Numerical	90%	No classification of vehicles, delay in exchanging data between software and hardware and dependency on predefined rules.
2020	Vehicles Counting from Video Stream for Automatic Traffic flow Analysis Systems	Gaussian Distribution, Bilateral Filter, Kalman Filter, Histogram of oriented Gradient and Hough Transform,	Video	95.14%	No classification, camera's position and angle vary from dataset to dataset, making it difficult to choose appropriate thresholds.
2022	Intelligent Traffic-Monitoring System Based on YOLO and Convolutional Fuzzy Neural Networks	YOLOv4-tiny, CFNN and Vector-CFNN	Video	90.45%	Motorcycle detection is not good in rainy conditions
2023	Computer Vision Application: Vehicle Counting and Classification System from Real Time Videos	GMM, BOF and Contour Comparison (CC)	Video	—	Inefficient in identifying vehicle occlusion and requiring human oversight to define the ROI, Night time vehicle detection is not possible, and the system is impacted by camera angle.
2023	Automated Vehicle Counting from Pre-Recorded Videos Using You Only Look Once (YOLO) Object Detection Model	YOLOv3	Video	90%	Precision is compromised when cars pass quickly and overlap, the video frame is small, and the quality is low.

Intelligent Traffic-Monitoring System Based on YOLO and Convolutional Fuzzy Neural Networks [3] is producing better result than Automated Vehicle Counting from Pre-Recorded Videos Using You Only Look Once (YOLO) Object Detection Model [2] and also using the

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later version of YOLO. The latter paper is included because the algorithm used is capable of providing the vehicle counts in both entry and exit directions whereas it is not the case in the first one. Based on the dotted center line passing direction through the reference line and parallel line, the algorithm calculates the number and directions of counts [2]. Since, we are also counting vehicles in two way directions hence the paper has been referred for that reason. We have employed pre-recorded traffic footage in our proposed approach to identify, count, and categorise vehicles. The traffic footage are first transformed into picture frames in our model, and then they are processed. YOLOv8, which is capable of accurately detecting small objects, is used to identify and categorise automobiles in each extracted frame. A virtual line is drawn for counting vehicles. When the vehicle passes through that virtual line, we increase the count of vehicles. The vehicles are classified into four categories: bus, truck, car and motorcycle. Some existing systems predominantly rely on counting the number of vehicles without considering their classification. This approach impedes the accurate assessment of road capacity utilisation, as larger vehicles inherently impact traffic flow differently than smaller ones. YOLOv8 improves upon its predecessors by enhancing detection accuracy and speed.

Materials and Methods

The goal of this project is to present a system based on computer vision for road vehicle counting. This is because users are constantly confronted with traffic flow congestion, particularly during peak hours. The accuracy of the car counts in this project, which uses a video streaming approach, is the issue. Our goal is to develop a model that increases vehicle counting accuracy. The model's intended use is in traffic monitoring systems. The construction of the vehicle counting and categorization model is the result of the research. Before the produced model is made accessible for the validity test, testing is done to find faults or other issues. Fig. 1 shows the main processes involved in the research methodology.

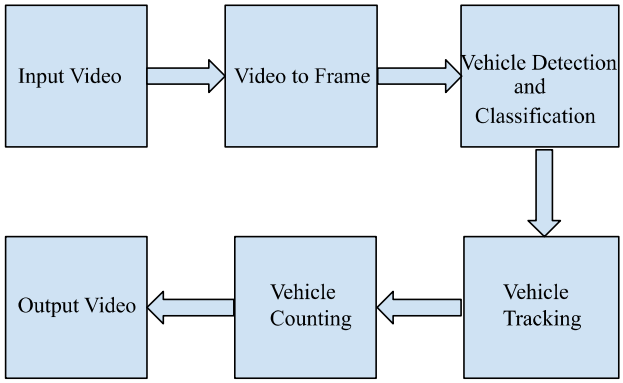
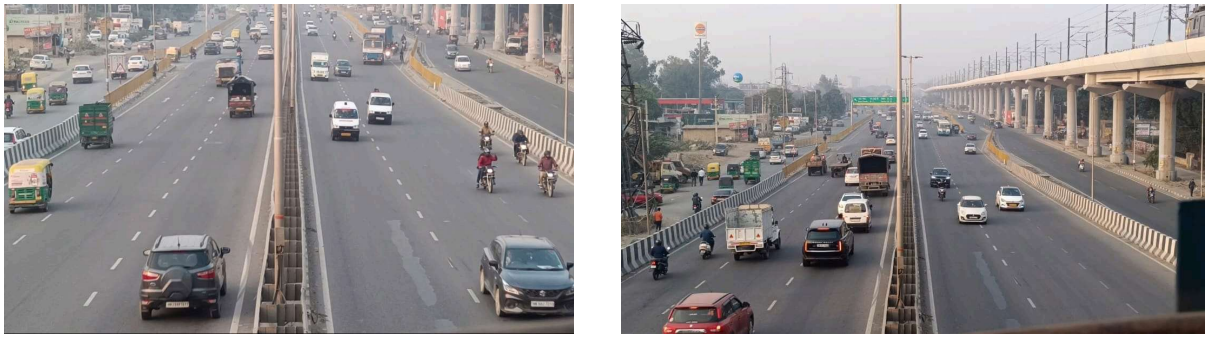


Fig.1. Block diagram of proposed system.

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Collection and Preprocessing of Video Data

The video footage of traffic movement was collected from the Mathura road near YMCA Chowk using a mobile camera. Three videos each of 10 minutes were collected during the evening time around 5PM from the site. All the videos were divided into parts of 10 seconds for deeper analysis and faster results. The created traffic counting and categorization approach was then used to analyse the video data in order to assess the model's effectiveness. Sample images of the dataset are presented in Fig 2.



(a) (b)

Fig.2.The testing dataset.

Vehicle Detection and Classification

This model starts with detection of the vehicle in the video frame. There are many libraries and algorithms for object detection and image segmentation. Some previous researchers had utilised the You Only Look Once(YOLO) object detection model for this purpose [2] [3]. YOLO version 8 has been selected for this research because it is superior to previous versions of YOLO in a number of important ways and has more features. Among the advancements in YOLOv8 are enhanced accuracy and faster detection speeds for small objects. It features an enhanced backbone network, multi-scale prediction, and an anchor-free architecture. The quicker frame-per-second (FPS) rate of YOLOv8 is one of its main advantages. Because of its speed advantage, YOLOv8 can process more frames in a given amount of time, which makes it ideal for real-time applications. YOLOv8's advanced model architecture makes it possible for object detection to be more precise and reliable. Furthermore, YOLOv8's mean average precision (MAP) scores have improved when compared to YOLOv7. In object detection systems, accuracy and precision play a critical role in determining the model's ability to locate and correctly identify objects within an image or video. Therefore, YOLOv8 is the best

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suitable model for this research purpose.

YOLOv8 directly predicts bounding boxes and class probabilities using a single neural network. The model is trained to recognize and classify various types of objects present in an image or a video frame. The neural network predicts bounding boxes (coordinates that define the position and size of an object) and assigns class probabilities to those bounding boxes. Each bounding box is associated with a particular class, representing the type of object the algorithm believes is present within that bounding box. For example, in a general vehicle detection scenario, common classes might include "truck," "car," "bus," "motorcycle," etc. The class probabilities indicate the confidence of the algorithm that a particular object of that class is present in the predicted bounding box. Fig. 3 shows the vehicle detection and its class in a video frame. The brief implementation is as follows:

1. Load the pre-trained YOLOv8 model with the specified weights.
2. Apply the model to each video frame to identify vehicles.
3. Extract bounding box coordinates, confidence scores, and class IDs from the detection results.

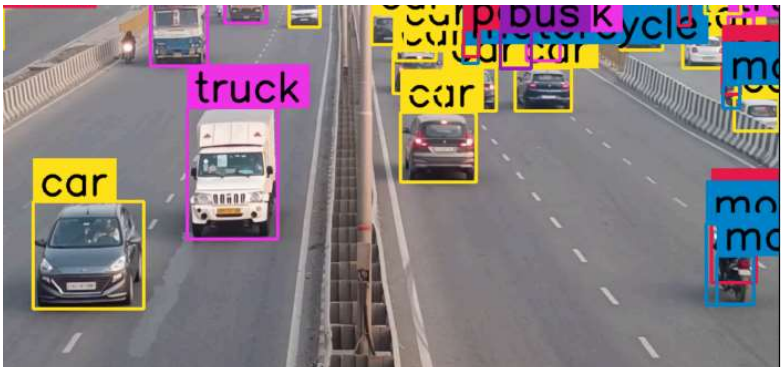


Fig.3.Vehicles detection and their respective classes.

Vehicle Tracking

The problem of counting vehicles only once, even if they appear in multiple frames, is addressed by vehicle tracking. One vehicle may move across the field of view in a video stream, resulting in several detections at various frames. Through the use of vehicle tracking, each vehicle is given a unique identifier (tracker ID), and the system follows its movement over a series of frames. This ensures that a vehicle entering the frame is identified as the same entity throughout its trajectory, regardless of intermittent detections.Without tracking, each detection in a frame might be counted independently, leading to overestimation of the actual

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number of vehicles. In our model, we have used BYTETrack which is a multi-object tracking computer vision model. Using the detection results from YOLOv8, BYTETracker updates each vehicle's internal tracker data. ByteTrack first uses an assignment algorithm like the Hungarian algorithm and a motion model like the Kalman filter to associate high-confidence detections across frames. In order to create a trajectory for each object, this step connects detections of the same object across multiple frames. ByteTrack distinguishes itself by incorporating low-confidence detections—which are normally disregarded—after linking high-confidence detections. If these detections coincide with the anticipated position and appearance of a tracked object, it associates them with current trajectories. This is an essential step in preserving an object's identity when it is obscured or not readily apparent. Track creation and deletion is handled by ByteTrack, which starts new tracks when it detects objects that don't match the ones that already exist and ends tracks that don't have enough evidence to support them in later frames. The implementation consists following steps:

1. Specify the classes of interest (e.g., car, motorcycle, bus, and truck) for vehicle tracking and counting.
2. Filter out detections corresponding to unwanted classes using the specified class IDs.
3. Initialise a BYTETracker instance with appropriate tracking parameters.
4. Update the tracker with the current frame's detection results, incorporating spatial and temporal information.
5. Match detections with existing tracks to maintain consistent vehicle identities.



(a) (b)

Fig.4.Vehicles annotated with Tracker-IDs.

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Algorithm for Vehicle Counting

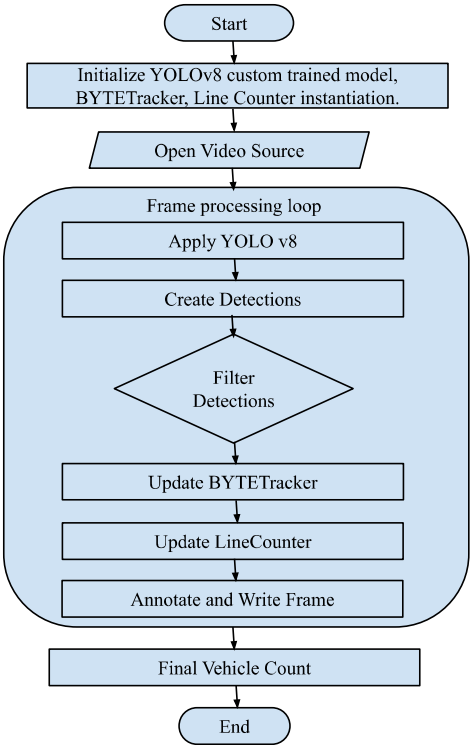


Fig.5. Flowchart of the model's algorithm.

Vehicle counts are calculated using the tracking data that BYTETracker provides. The counting logic, which involves tracking distinct vehicles as they move through a virtual defined line of interest, is integrated into the processing of each video frame. Supervision, a Python library, is used to count vehicles that have crossed the reference line. Algorithm for counting vehicles is given below and Fig.5 shows the flowchart for the same.

1. Before processing the video frames, a LineCounter instance is created. The LineCounter is designed to count vehicles based on their movement across the defined line in the video frame.
2. The code enters a loop where each frame of the video is processed one by one. This loop iterates over the frames obtained from the video source.
3. Within the frame processing loop, the YOLOv8 model is used to perform object detection, and BYTETracker updates the tracking information for each vehicle in the frame.
4. Detections are filtered to include only those corresponding to the specified vehicle

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classes (e.g., cars, motorcycles, buses, trucks).

5. The LineCounter is then updated with information about the filtered detections. This step involves checking whether each vehicle has crossed the defined line.
6. The annotated frame, which includes bounding boxes and labels for the detected and tracked vehicles, is written to the target video file.
7. The line_counter instance keeps track of the cumulative count of vehicles that have crossed the defined line during the video sequence.

Evaluation metrics

The error and accuracy of the vehicle counts are determined using the following formulas [5]:

Average Error: The percentage of all predictions that turn out to be wrong.

$$Average\ Error = \frac{|\ Program\ count - Actual\ Count\ |}{Actual\ Count} \times 100$$

Accuracy: The percentage of all predictions that come out right.

$$Accuracy = 100 - average\ error$$

Experimental setup

The hardware platform configuration affects the program's counting speed. In this study, Google Colab platform was used to run the program:

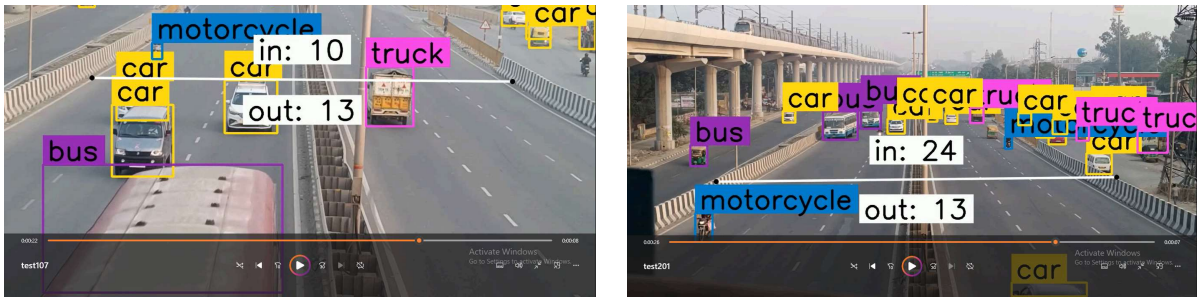
CPU: 4 cores of Intel Xeon E5-2680 v4 (Broadwell)
RAM: 16 GB of DDR4 RAM
GPU: 1 NVIDIA Tesla K80 GPU
Storage: 256 GB of SSD storage
Network: 1 Gbps network connection

It was discovered that this platform's software requires roughly 12 seconds to process a 10-second video. It is advised to process videos on a high-configuration computer in order to maximise processing performance. Python was used for developing the algorithm.

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Results and Discussion

The system's implementation, the tests that were run, and the outcomes are covered in this section. Fig. 6 shows the results from some output videos obtained.



(a) (b)

Fig.6. Results from output.

The selection of appropriate coordinates for the reference line presents a hurdle in this work because the camera's position and angle vary between datasets. The system will not count the cars correctly and may give erroneous results if the reference line is not placed in the proper location. Since, YOLOv8 models are pre-trained on the COCO dataset and this dataset doesn't contain auto objects, this leads to classification of autos as car or bus. This is one of the limitations of this model. To overcome this problem, the model can be trained on datasets of auto. If we don't consider this factor for the evaluation of the model accuracy for classification, the model achieves accuracy of about 95%.

In comparison to other models, motorcycle classification has achieved higher accuracy. The model is not tested on the dataset of the traffic during the night time due to availability of limited dataset. The testing findings for every video record are displayed in Table 2.

Table 2. Testing results

Dataset	Manual count of lane 1	Automated count of lane 1	Manual count of lane 2	Automated count of lane 2
Video 1	335	332	378	333
Video 2	135	132	174	172
Video 3	306	272	323	310

Based on the findings of Table 2, Table 3 then displays the accuracy and error outcomes. In this table, which shows the average error findings, video 2 has the lowest error - 1.62% while

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video 1 has the error - 6.73% and video 3 has the highest error - 7.47%.

Video 2 results in the highest accuracy of 98.38%. The model achieves average vehicle counting accuracy of 94.73%. The undercounting of the vehicles in the results is due to occlusion of vehicles behind other vehicles.

Table 3. Overall results

Parameters	Video 1	Video 2	Video 3	Overall
Accuracy	93.27%	98.38%	92.53%	94.73%
Average Error	6.73%	1.62%	7.47%	5.27%

Conclusion

The integration of YOLOv8 and Ultralytics, along with the implemented tracking mechanism, results in a valuable tool for traffic monitoring and management. The project provides a foundation for further research and applications in the field of intelligent transportation systems.

In future, this traffic monitoring system can be integrated with a Traffic Light Expert System. The aim of the expert system is to apply a dynamic cycle time by altering the time for traffic signals depending on the count and classes of vehicles obtained from this monitoring system. Four bidirectional roadways' traffic lights are controlled by the system. The limitations of conventional traffic systems become apparent in emergency situations, where prioritising the lane containing emergency vehicles and allowing it to pass is crucial for effective emergency response and traffic management. This system can be integrated with detecting emergency vehicles in a lane and then allowing that lane to pass first.

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BIOSYNTHESIS AND APPLICATION OF SILICA-COATED ZINC OXIDE NANOCOMPOSITE FOR REMOVAL OF LEAD (II) IONS FROM SIMULATED WASTEWATER

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Abstract

The current work evaluated the capacity of Silica-coated zinc oxide nanocomposite (Si-ZnO NC) to remove Pb (II) ions from simulated wastewater. Si-ZnO NC was fabricated utilizing a green synthesis strategy and co-precipitation method. The produced Si-ZnO NC was characterized by FTIR, XRD, SEM-EDX and BET analysis. The influence of various operating variables like- pH, initial metal ion concentration, adsorbent dose, contact time and temperature were investigated on Pb (II) removal. The maximum removal efficiency of Si-ZnO NC for Pb (II) ions removal was found to be 94.6% at pH 6.5, equilibrium time 60 min, and adsorbent dose. The adsorption data was found to follow pseudo second order kinetics and Langmuir isotherm model. Thermodynamic variables including enthalpy change (ΔH^0), free energy change (ΔG^0), and entropy change (ΔS^0) were computed and results revealed that adsorption is spontaneous and endothermic. Regeneration assessment was also carried out using 0.1M NaOH as desorbing agent.

Keywords: Si-ZnO NC, Pb (II) adsorption, isotherm models, kinetics, reusability

1. Introduction

There is not enough water in many nations to meet human demand due to rapid industrialization and population growth. Most of the available water resources are severely polluted due to addition of industrial effluents and sewage. Heavy metals are among prime sources of polluted water, they are highly harmful even at modest levels. Therefore, treating wastewater as a part of water security strategy has become a top priority for nations [1]. Lead, Pb (II) is among the most hazardous metals that can end up in the environment as a consequence of various industrial processes. In addition, batteries, pipelines, artworks, lead plates, technological goods and healthcare devices have all been contain Pb [2]. Pb (II) ions get attach to red blood cells (RBCs) and eventually accumulate into bones. Humans adsorb around 20-80% of inorganic Pb by ingestion and 5-15% by inhalation [3]. Pb (II) exposure harm human kidneys, liver, nervous system and reproductive system, which leads to cancer, irritability, anemia, weakness of muscles, kidney dysfunction and mental impairment especially in children [4]. Due to its harmful properties, Pb is crucial for the well-being of society and environment to remove it from water & wastewater. Various approaches including ozonation, membrane filtration, ion exchange, biological treatment, adsorption and electrochemical

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techniques have been documented for removing heavy metals from wastewater [5-8]. Owing to the health risks, operational expenses and production of hazardous byproducts associated with previously mentioned technologies, adsorption has been proposed as an effective, economical and flexible technique. The effectiveness of adsorption is greatly affected by adsorbent properties and process conditions [9]. The genesis of innovative nano-adsorbents to eliminate harmful metal ions from aqueous environment has drawn interest because of recent advancements in field of nanotechnology. Nanoparticles of Zinc oxide (ZnO) have shown good efficiency in water treatment and environmental remediation owing to their band gap, low toxicity photocatalytic potential, antibacterial action and optical properties [10]. Additionally, Silicon dioxide (SiO_2) nanoparticles have also shown good potential for selective Pb (II) ions removal because of their lesser toxicity, ease of surface modification, low cost of production and porosity [11]. Different methods are used to prepare these adsorbents but they are labor-intensive, chemically demanding and expensive. Thus, it is desirable to produce adsorbents by ecologically and economically sound processes. In this work, novel Si-ZnO NC was fabricated using biogenic green synthesis approach. Si-ZnO NC was prepared using rice husk extract as silica source. Rice husk or rice hull is the outer layer of rice grain and a by-product of rice milling. Despite being a byproduct of agriculture, rice husk is regarded as a good source of silica [29]. Though some of the work has been conducted using Si-ZnO NC as adsorbent but the possibilities of heavy metal removal are yet to be explored [30,31]. So, in this research we have investigated the removal of Pb (II) ions using Si-ZnO NC through batch mode method. Analytical methods like XRD, FTIR, SEM-EDX and BET were employed to evaluate the functionality, bonding, formation and morphology of Si-ZnO NC. The impact of pH, metal ion concentration, nanocomposite dose, contact time and temperature were conducted to evaluate Pb (II) ions removal on surface of Si-ZnO NC. Various isotherms and kinetic models were also utilized to estimate the effectiveness and maximum sorption capacity.

2. Materials and Methods

2.1 Chemicals used

Every chemical utilized was of analytical grade and bought from CDH Ltd. Dilute hydrochloric acid (dil. HCl), Sodium hydroxide (NaOH) and Zinc nitrate hexahydrate $(ZnNO_3)_2$. $6H_2O$ were used in Si-ZnO NC synthesis. Initial solution of Pb (II) was made with $Pb(NO_3)_2$. The Rice husk utilized in this study was collected from a nearby mill at Bhupani Sec-88 Faridabad, India as a processing waste.

2.2 Synthesis of Si-ZnO NC

Si-ZnO NC was synthesized via modification of already reported method [12]. Washing of rice husk was first done with tap water. Afterward, it was washed with dil. HCl followed by deionized water. It was then sundried and ground to make a powder for further usage. 25g of powdered rice husk was stirred with 2M NaOH solution at 80°C for 3 hours. The obtained extract was then treated with 0.1 M zinc nitrate hexahydrate solution in 1:1 ratio with constant stirring at 80°C. Mixture obtained was stirred for 24 hours, centrifuged and washed with deionized water. After being washed, Si-ZnO NC was dried in a hot air oven and stored for later adsorption tests.

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2.3 Characterization of prepared Si-ZnO NC

The Fourier transform infrared analysis (Shimadzu IR AFFINITY-I, Japan) was carried out using KBr powder under 4000 - 400 cm^{-1} range of spectrum array to identify the surface functionalities of the nanocomposite. X-ray diffraction (XRD) analysis was completed using Panalytical X Pert Pro having Cu K_α X-ray radiation within 20 - 80° and 2°/min scanning rate. The surface organization and configuration analysis of nanocomposite were investigated by Field Emission Scanning Electron Microscope (FESEM) and Energy Dispersive X-ray spectroscopy respectively with FESEM Carl Zeiss (Merlin Compact 6073, Germany). The specific surface area and pore size distribution of fabricated nanocomposite were examined with BET analyzer (BELSORP-MaxII) at 77.35 K.

2.4 Pb (II) removal experiments

Batch mode study was performed for sequestration of Pb (II) ions by Si-ZnO NC from simulated wastewater. 25 mg of Si-ZnO NC was put in a 250 mL conical flask holding 50 mL metal solution, pH calibration was done by adding 0.1 M NaOH and 0.1 M HCl to attain adsorption equilibrium. Thereafter, this mixture was shaken for 120 min at 200 rpm at 25° C in a closed orbital shaker. The adsorption conditions including pH, Pb (II) concentration, temperature, time and nanocomposite dose were optimized through experiments. pH of solution was changed from 2-10 to examine the influence of pH. Through experimenting with an optimized pH, the influence of contact time (10-180 min) was determined. Adsorption study was carried out by varying initial concentration of Pb (II) ions (10-60 mg/L), temperature (15-45°C) and adsorbent dose (0.1-1 g/L). After adsorption, spent adsorbent was centrifuged off and remaining amount of Pb (II) in supernatant examined using Microwave Plasma - Atomic Emission Spectroscopy (Agilent, 4210 MP-AES). Adsorption capacity (mg/g) and removal efficiency (%) were calculated using Eq (1) and (2) respectively.

$$\text{Adsorption capacity } (q_e) = \frac{(Co - Ce)V}{m} \quad (1)$$

$$\text{Removal efficiency } (\%) = \frac{Co - Ce}{Co} \times 100 \quad (2)$$

Where C_o = Initial Pb (II) ions concentration (mg/L),
C_e = Final Pb (II) ions concentration (mg/L),
m = Mass of Si-ZnO NC (g),
V = Solution volume(L).

3. Results and Discussion

3.1 FTIR (Fourier Transform Infra-Red) Spectroscopy

FTIR pattern of Si-ZnO NC with characteristic peaks is shown in Fig. 1. Absorption peaks at 3738.21 cm^{-1} and 3381 cm^{-1} denote possible existence of hydroxyl group on nanocomposite surface. Weak peaks at 2923.88 cm^{-1} and 2852.91 cm^{-1} corresponds to methylene group's C-H stretching vibration in Si-ZnO NC. The signature peak at 1649.48 cm^{-1} indicates C=O molecule stretching whereas distinctive peaks at 1481.22 cm^{-1} and 1406.8 cm^{-1} are representative of C-H bending vibrations [13]. Si-O stretching vibrations are responsible for a prominent peak at 1003.31

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cm^{-1}, confirming the incorporation of silica into the nanocomposite as synthesized. FTIR peak at 537.31 cm^{-1} consigned to presence of Zn-O-Zn stretching, thereby confirming the fabrication of ZnO nanoparticles.

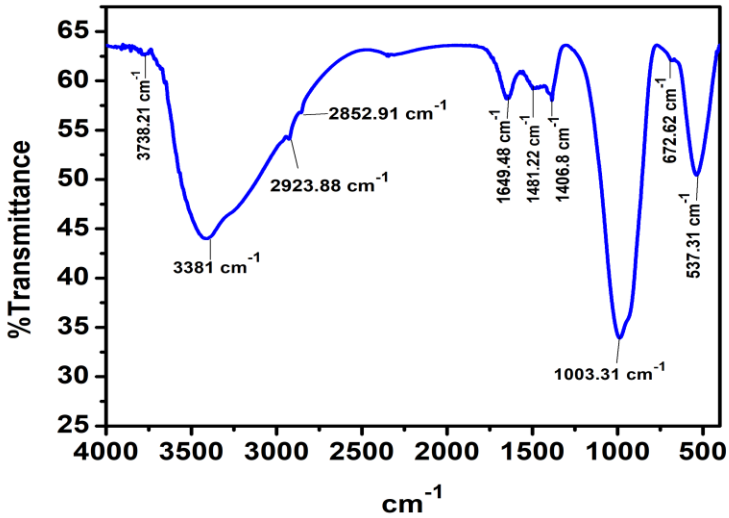
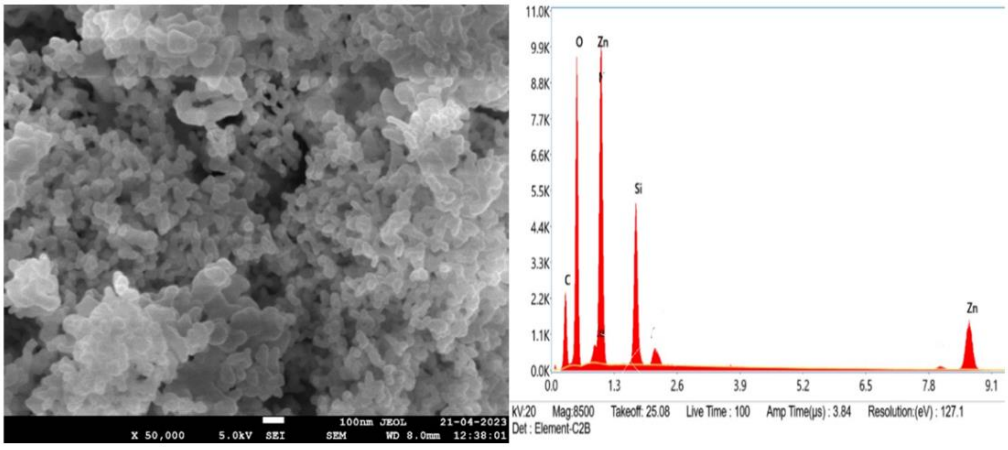


Fig 1: FTIR analysis of Si-ZnO NC

3.2 SEM-EDX analysis

SEM analysis had been carried out to explore surface morphology of nanocomposite (Fig. 2a). It revealed that the bio-fabricated nanocomposite possesses roughly spherical particles in agglomerated form. The presence of porous surface and small globule like structure that facilitates for diffusion of adsorbate can also be seen. Fig. 2b represents the elements and spectrum of Si-ZnO NC from EDX analysis. The EDX spectrum revealed that O (33.2%), C (8.8%), Zn (41.6%) and Si (16.4%) are the major components in the obtained nanocomposite.



(a) (b)

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Fig 2: (a) SEM analysis (b) EDX analysis

3.3 XRD (X-Ray Diffraction) analysis

Fig. 3 depicts the XRD spectra of Si-ZnO NC. Diffraction peak at 2θ = 21.22º is distinctive for silica. The XRD pattern of synthesized nanocomposite showed a broad hump suggesting amorphous nature. Since, rice husk is organic matter and silica was extracted from the waste rice husk, noise in the XRD pattern is indicative of amorphous nature of adsorbent [14]. The amorphous materials generally have high surface area and increase the force of interaction between adsorbent and substrate material which leads to increase in overall adsorption efficiency. The main diffraction peaks at 2θ = 31.08º, 36.06º, 46.16º, 56.23º and 67.76º validated the existence of zinc oxide [15]. Thus, result verified that the synthesized nanocomposite contained zinc oxide and silica.

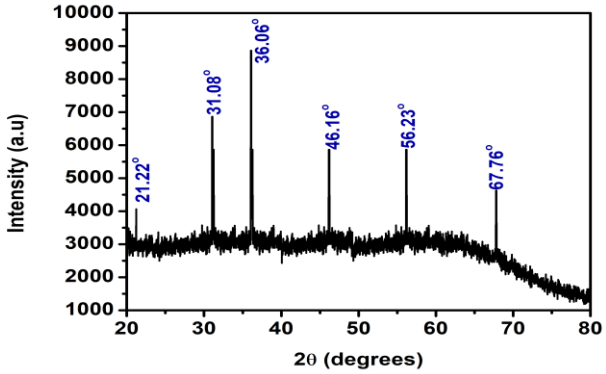


Fig 3: XRD analysis

3.4 BET (Brunauer-Emmett-Teller) assessment

The BJH pore size distribution and nitrogen adsorption - desorption plot between relative pressure (P/P^o) and volume (cm^3g^{-1} at STP) of Si-ZnO NC were analyzed using BET analyzer. Results revealed the values of BJH mean pore diameter and total pore volume to be 27.964 nm and 0.1895 cm^3g^{-1} respectively, indicating that the nanocomposite is mesoporous according to IUPAC classification. BET - specific surface area of Si-ZnO NC was determined to be 27.113 m^2g^{-1}. The isotherm curve of Si-ZnO NC showed Type III isotherm with hysteresis between P/P^o range 0 - 0.99 (Fig. 4).

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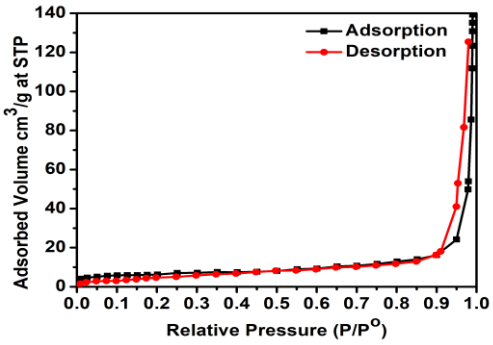


Fig 4: Nitrogen adsorption - desorption isotherm plot

3.5 Point of zero charge

The pH_{pzc} of Si-ZnO NC was found to be 4.8 as shown in Fig. 5, indicating neutral net surface charge of nanocomposite. Below this value, the surface of nanocomposite acquires positive charge and therefore favors anionic adsorption. For pH value above pH_{pzc}, negatively charged Si-ZnO NC surface makes cationic adsorption more efficient.

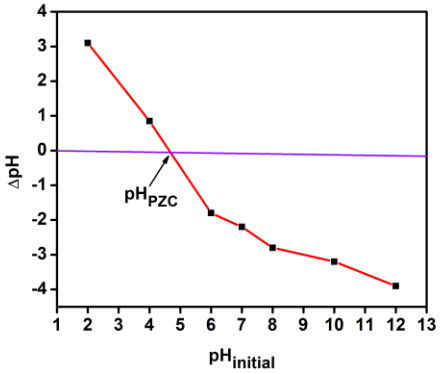


Fig. 5**:** Plot for pH_{pzc} determination of Si-ZnO NC

3.6 Effect of initial pH

The influence of pH on Pb (II) adsorption was examined for pH 2-10, keeping rest of the process conditions unchanged. Pb (II) removal efficiency increased from 21.4% to 96.9% on increasing the reaction pH from 2 to 10 (Fig 6a). Lesser removal of lead ions at pH < pH_{pzc} may be attributed to electrostatic repulsion between metal ions (Pb^{2+}, $Pb(OH)^{+}$) and protonated Si-ZnO NC surface [19,20]. At pH > pH_{pzc}, Pb (II) removal was greater owing to adsorption along with precipitation of metal ions as $Pb(OH)_2$ and deprotonation of protonated adsorbent surface. The solubility of Pb (II) ions depend on solution pH. Lead (II) is very soluble at reduced pH levels and can be found as $Pb^{2+}$and $Pb(OH)^{+}$. However, at pH values over 6, Pb (II) ions precipitate as $Pb(OH)_2$ [21]. Therefore, every adsorption investigation was done at pH 6.5 to precisely ascertain removal effectiveness of lead ions.

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3.7 Effect of initial lead concentration

The removal efficiency followed a decreasing trend on increasing lead concentration and highest removal i.e., 94.4% was recorded at 10 mg/L (Fig 6b). Reason behind this decline in removal efficiency is the availability of active sites at a constant adsorbent dose, which was greater at low lead concentration but fewer at high lead concentration [24].

3.8 Effect of Si -ZnO NC dose

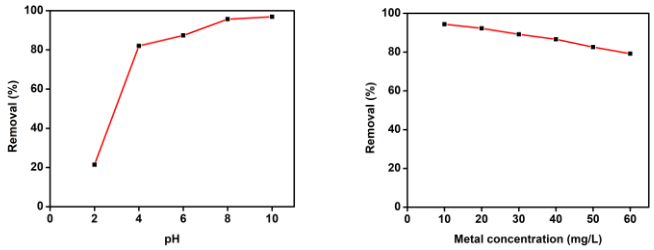
Adsorbent dose is a crucial aspect since it affects the operational budget. Fig 6c illustrates removal efficiency of Pb (II) ions at different Si-ZnO NC dose. Results suggest that effectiveness of removal rose from 72.8% to 94.6% as the Si-ZnO NC dose was raised from 0.1g/L to 0.5g/L, after which no significant change was observed on further dose increament. This can be attributed to the fact that the rise in amount of Si-ZnO NC produced huge surface area and lots of empty sites, while metal ions were limited [23].

3.9 Effect of contact time

Contact time is a prime determining component in the process of adsorption. Adsorbent-adsorbate interaction is enabled by sufficient period of contact. Impact of contact time on Pb (II) sequestration was explored for 10 to 180 min. Fig 6d clearly indicates that adsorption happened quickly during first 60 min due to enormous number of free active sites. Removal efficiency shifts from 86% to 94.6% as the time of contact increased from 10 to 60 min after which, equilibrium is reached and no more free active sites were available [25].

3.10 Effect of temperature

At optimum experimental conditions, temperature in the range of 15-45° C was examined for its effect on Pb (II) removal using Si-ZnO NC. It was observed from the results (Fig 6e) that the removal efficiency followed an increasing trend with increasing temperature. Greater removal efficiency at higher temperature indicates endothermic nature of adsorption reaction. Moreover, higher temperatures facilitate passage of ions and increase contact between metal ions and adsorbent surface [26].



(a) (b)

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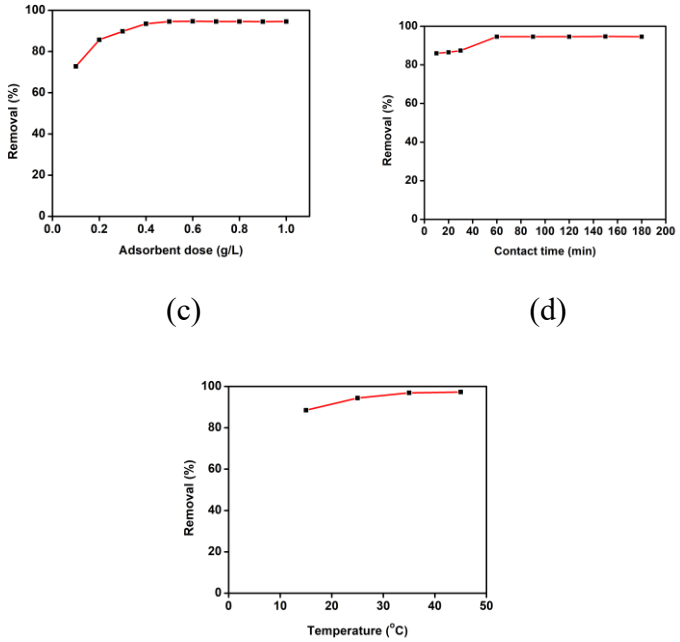


Fig 6: (a) Effect of pH on Pb (II) adsorption (b) Effect of metal concentration on Pb (II) adsorption (c) Effect of adsorbent dose on Pb (II) adsorption (d) Effect of contact time on Pb (II) adsorption (e) Effect of temperature on Pb (II) adsorption

3.11 Kinetic and isotherm analysis

Pseudo-first order (PFO) and pseudo-second order (PSO) kinetic models were examined in order to comprehend Pb (II) adsorption kinetics by Si-ZnO NC. To study PFO model, log (qe – qt) vs T(min) was drawn. Further, PSO reaction was studied to compute the adsorption rate constant from intercept of t/qt vs T(min) plot. The correlation coefficients and constants of kinetic model were computed and presented in Table 2, which suggested that adsorption kinetic reaction complies with PSO model ($R^2 = 0.9999$). This could imply that the square of no. of empty reaction sites determine exact rate of Pb (II) adsorption [16] and adsorption was the main controlling factor for Pb (II) elimination by Si-ZnO NC [17]. Langmuir, Freundlich, Temkin, and Dubinin-Radushkevich (D-R) have all been assessed in order to explore the interaction amongst Pb (II) & Si-ZnO NC. The correlation coefficients and constants for above mentioned isotherm models were computed and arranged in Table 2. Research findings for Pb (II) sequestration complemented to Langmuir model because of a greater correlation coefficient ($R^2 = 0.9943$), that implies monolayer adsorption onto Si-ZnO NC surface [18]. The value of $E < 8$ in (D-R) suggesting physisorption [19]. Langmuir isotherm's characteristic, R_L, was found to be between 0 to 1, indicating that Pb (II) ions would adsorb well on Si-ZnO NC.

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Table 1: Kinetic and adsorption isotherm models

Kinetic models	Equations	Parameters
PFO	$Log(q_e-q_t) = \log q_e - k_1/2.303\ t$	q_e: adsorption capacity at equilibrium(mg/g) q_t: adsorption capacity (mg/g) at time t (min) k_1: rate constant (min^{-1})
PSO	$t/q_t = 1/k_2q_e + (1/q_e)\ t$	k_2: rate constant (g/mg min)
Adsorption isotherms		
Langmuir isotherm	$C_e/q_e = 1/bq_{max} + (1/q_{max})\ C_e$ $R_L = 1/1+bC_o$	b: Langmuir constant (l/mg) q_{max}: maximum adsorption capacity (mg/g) R_L: separation factor
Freundlich isotherm	$lnq_e = lnk_f + (1/n)lnC_e$	$k_{f:}$ Freundlich constant n: adsorption strength
Temkin isotherm	$q_e = (RT/b)lnk_t + (RT/b)lnC_e$	b: Temkin constant R: universal gas constant (8.314 J mol^{-1} K^{-1}) K_t: equilibrium binding constant (mol/l) T: temperature (K)
D-R isotherm	$Lnq_e = lnq_m - \beta\varepsilon^2$ $\varepsilon = RTln(1 + 1/C_e)$ $E = 1/(2\beta)^{0.5}$	β: activity coefficient Ɛ: Polanyi potential E: adsorption energy

Table 2: Parameters and their values for kinetic models and adsorption isotherms

Parameters for kinetic models				
PFO	**K_1 (min^{-1})**	**q_e (mg/g)**	**R^2**	
	0.0004	7.8743	0.7374	
PSO	**K_2 (g/mg min)**	**q_e (mg/g)**	**R^2**	
	0.0167	19.308	0.9999	
Parameters for adsorption isotherm				
Langmuir	**q_m (mg/g)**	**K_L (L/mg)**	**R_L**	**R^2**
	101.42	0.4029	0.1988	0.9943
Freundlich	**1/n**	**K_f**	**R^2**	
	0.5181	27.65	0.9835	
Temkin	**K_T (L mg^{-1})**	**B_T (J mol^{-1})**	**R^2**	
	3.2632	24.64	0.9818	

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D-R	q_m (mg/g)	β (mol^2/KJ^2)	E (KJ/mol)	R^2
	56.02	0.4793	1.4707	0.83723

3.12 Thermodynamic study

Thermodynamic assessments of Pb (II) adsorption were conducted at 15°C, 25°C, 35°C, and 45°C. The thermal influence on sequestation of Pb (II) ions by Si-ZnO NC was assessed to determine adsorption related thermodynamic variables like Enthalpy (ΔH^o), Entropy (ΔS^o) and Gibbs free energy (ΔG^o). Equations shown below have been employed to determine these parameters [22]:

$$\Delta G^o = -RT\ln K_d \quad (12)$$

$$\Delta G^o = \Delta H^o - T\Delta S^o \quad (13)$$

$$K_d = C_a/C_e \quad (14)$$

$$\ln K_d = \Delta H^o/RT - \Delta S^o/R \quad (15)$$

Where C_a (mg/L) indicates quantity of lead adsorbed on Si-ZnO NC, C_e (mg/L) indicates quantity of Pb (II) at equilibrium, T (K) indicates temperature, R (8.314 J mol^{-1} K^{-1}) is gas constant and K_d is equilibrium constant.

The positive value of ΔH^o for Si-ZnO NC (40.263 KJ mol^{-1}) assumes endothermic process of removal (Table 3). The spontaneity and feasibility of adsorption for Pb (II) were expressed by negative value of ΔG^o. Moreover, the positive value of ΔS^o (146.25 $Jmol^{-1}$ K^{-1}) validates the rise in extent of movement at solid - liquid interface at time of adsorption, which would increase the affinity of Si-ZnO NC for Pb (II) [27,28].

Table 3: Thermodynamic variables

T (°C)	ΔG^o (KJ mol^{-1})	ΔH^o (KJ mol^{-1})	ΔS^o (J mol^{-1} K^{-1})
15	-1.5668		
25	-3.5639		
35	-5.2648	40.263	146.25
45	-5.8119		

3.13 Regeneration and reusability

Adsorbent regeneration is a key parameter in treatment and removal processes. This study was performed up to three passes utilizing 0.1 M NaOH solution as desorbing reagent and data was plotted in Fig 7. Results make it quite evident that Pb (II) removal was exceeding 90% for first two cycles of reuse after which, it slightly reduced to 86%. Therefore, it can be stated that Si-ZnO NC has a minimum three cycle reuse limit when it comes to eliminating heavy metals.

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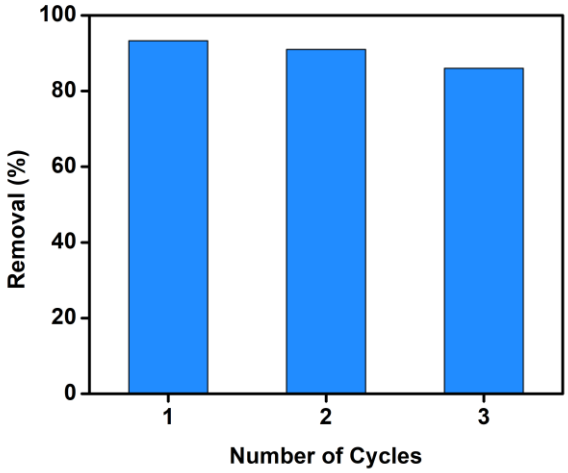


Fig 7: Reusability potential of biofabricated Si-ZnO NC for Pb (II)

4. Conclusions

In this work, Si-ZnO NC, a novel and environmentally acceptable adsorbent was fabricated and employed for removing Pb^{2+} ions from simulated wastewater. FTIR, XRD, SEM-EDX and BET analyzers were used for description and identification of adsorbent. The removal effectiveness of Si-ZnO NC for Pb^{2+} ions was found to be 94.6% at pH 6.5, equilibrium time 60 min, and adsorbent dose 0.5g/L. A stronger correlation coefficient (R^2 = 0.999) suggested that PSO model described the adsorption reaction's kinetics. The isothermal findings show that because of greater correlation coefficient (R^2 = 0.9959), adsorption reaction corresponds to Langmuir isotherm. Thermodynamic variables such as enthalpy change (ΔH^0), free energy change (ΔG^0), and entropy change (ΔS^0) were computed and results revealed that sorption process is spontaneous and endothermic. Regeneration and reusability test was performed by making use of 0.1 M NaOH as desorbing reagent and outcomes of study disclosed that removal effectiveness for Pb^{2+} exceeded 90% for two passes before declining to 86%. It is noteworthy to remark that the Si-ZnO NC has a minimum of three cycles of reuse when it comes to removing heavy metals from wastewater.

Acknowledgement

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Analyzing Traditional Courtyard Structures and Architectural Elements to Develop Framework for Enhancing Thermal Comfort: A study for Cfa climate type

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Abstract

Thermoregulation is an important factor that has been considered for old and modern residential structures. This study assesses the impact of architecture in a region classified under the humid subtropical climate (Cfa). Both survey-based as well as field based data was collected and amalgamated to obtain information regarding the architectural features that were responsible for promoting thermal comfort in the studied area. Characteristics such as presence of shading (artificial/natural), natural elements (eg: trees, ponds etc.), orientation of the courtyards were recorded for 150 houses across the studied region. The temperatures were also assessed for both the semi-enclosed and fully-enclosed courtyards to get a comparative and data-based output regarding the one that ensured thermoregulation. Some local and sustainable materials like Bamboo fences and specially woven mats called 'paati' was found to provide significant cooling effect during humid summers and was often used for shading purposes. Based on the survey and experimental evidences and data analysis a basic framework was designed that elaborated on the measures that could provide optimum thermal comfort for houses with courtyards in the humid subtropical climate. The ultimate of the study was to amalgamate the concept of Thermoregulation under modern sustainability paradigms, with already existing architectural wisdom, thus fostering a beneficial symbiotic relationship. Moreover, as similar studies are rare for this climate subtype, hence this paper will act as one of the foundational keystones to promote buildings that are thermally regulated and aligned for the humid subtropical climate.

Keywords: Courtyard architecture, Cfa Climate, Thermal Regulation, Design, Environmental Aspect

Introduction

The courtyard is a type of architectural feature that has its roots in regions with arid and hot environments. A courtyard is a confined exterior or partially exterior space that is exposed to the sky and enclosed by constructions [1]. The majority of traditional architecture of the Middle Eastern countries, Asia, and regions surrounding the Mediterranean Sea use courtyards [2-4]. Their purpose is to enhance airflow and change the environment surrounding the building to increase

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comfort levels. Over the ages, several paradigms have been used to construct courtyards in various nations (and climates). The study of courtyard relies mostly on air circulation, the interplay of light and shadows, and established structures on it [5]. Dunham [6] reports on one of the first initiatives to look into the thermal efficiency of courtyards. Airflow patterns inside a courtyard were thereafter demonstrated and computational fluid dynamics (CFD) and wind tunnel simulations were used to validate the capability of courtyards to ensure sufficient air circulation and optimized airflow [7-8]. Comparably, it has been shown that courtyard shading organically contributes to thermal comfort [7,9-10]. They also play significant roles in allowing air to circulate naturally, maximizing radiative behavior, and bringing in natural light [11]. Courtyards are said to be extremely effective in improving aeration and minimizing moisture levels. Additionally, a substantial association between the exterior temperature of the wall surfaces of the courtyard and the air inside the building also exists [12]. Involving biotic or abiotic natural elements, such as non-invasive flora, is a highly suggested way to enhance courtyard performance [13]. To boost the thermal comfort of the outdoors in courtyards in hot and humid areas, trees are planted to create high shade levels [14]. Similarly, incorporating the presence of water reservoirs promotes local thermal comfort [14].

The global climate has been conceptually classified by Wladimir Köppen's under his climate classification framework, which is divided into five main climatic groups as shown in Fig.1. The current study is conducted in the northeastern state of India, Tripura, which is characterized by its Cfa climate type which comes under class C of this classification framework. Summers in the humid subtropical climate (Cfa) are hot and muggy, with thunderstorms predominating. Mid-latitude cyclones are the source of precipitation during this season, which has moderate winters [15-17]. An extensive survey was done with a total of 150 houses across the state of Tripura. Also, the temperatures of semi-enclosed and fully-enclosed courtyards were assessed by taking field measurements.



Fig.1. Köppen's Classification System

Studying the architectural elements for the Cfa climate is highly significant as it will help in bringing up frameworks for construction of more sustainable architecture that will enhance thermal comfort of the residents and also exist in a symbiotic association with its surrounding environment. Environmentally, it is highly relevant because with a rise in urban culture, there has also been a surge of 'not-so-eco-conscious' constructions that requires urgent replacement with better alternatives and elements. Moreover, the association of climate-specific architecture, especially for Cfa climate has not been conducted earlier. In this article, one can expect to get an overview of the courtyard structures in grassroots situation and also get a structured framework that will

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encompass the key constructive takeaways for architecture in similar sub tropical and humid climates.

Materials and Methods

The first phase of the study included an indoor and outdoor temperature study for both houses with fully-enclosed (O-shaped) and semi-enclosed (U and L-shaped) courtyards. Under this part, field readings were recorded and the experimental set up is described below. The second part included a structured survey, the methodology of which was adopted from a study on the diversity in designing elements of courtyards in several hospitals of Malaysia [18]. A set of characters as displayed in Table 1, was used as a foundation of information that was to be collected. The survey was carried out across the state of Tripura, in northeast India for 150 numbers of household between the months May to October. Both recently-built as well as houses with older origins were investigated under this survey using random sampling. It was based upon observation of the surveyor after visiting the 150 houses. The observations were meticulously recorded along the temperature readings. For certain houses the head member of the families were interviewed and the conversation was mostly kept agile and free-ended so that the owners can share as much information to the surveyor's benefit. They were mainly questioned regarding the elements or aspects like presence or absence of ponds, certain specific trees, to gather relevant information.

Table 1: List of Building Features Studied During the Survey

Building Features	Characteristics
Design	O-shaped (Fully enclosed), U-shaped (Enclosed in 3 sides), L-shaped (2 sides enclosed), and Others
Orientation	North, South, East, West, North-West, North-East, South-East, South-West
Shading	Special roofing, tree cover, overhangs, etc.
Incorporation of natural elements	Presence of vegetation or water bodies
Utility of Courtyard	Ventilation, Recreation, Household chores, etc.

Experimental Setup and Methodology

For the temperature study, a sensor-wired mini LCD digital thermometer with a temperature range of -50 ºC to 70 ºC was used to record temperatures of fully and semi-enclosed courtyards. The thermometer was placed 1.5m above the surface of the courtyard on an elevated platform and at least at a distance of 1.5m from the peripheral surface of the walls [19]. The temperatures were recorded for the courtyards during the warmest hours of the day i.e. between 1400-1600 hrs. The 4 sets of readings were taken from each courtyard after calibration of the thermometer and the average of these four readings was recorded as the mean temperature for that particular courtyard. The Photo1 shows different courtyards studied with different shading elements and materials. White corrugated plastic sheets were used as a protection from direct sunlight and the thermometers were kept under the partial protection of these. Several other considerations included checking and removing all other sources that could hinder with the readings of the thermometer.

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The houses that had a sheltered north did not require the plastic sheets and the thermometer was placed on the raised platform to record the temperatures.







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Photo1: Different Courtyards Studied with Different Shading Elements and Materials.

Results and Discussion

The O-shaped, U shaped and L shaped houses were found along with I-shaped rectangular and irregular shaped courtyards. Among this, U shaped courtyards were the most abundant with 37.33% of the houses across the surveyed houses having this shape, followed by 34.67% L-shaped and 28% O-shaped houses as depicted in Fig.2. It is evident that fully-enclosed houses (O-shaped) were much lesser in number as compared to semi-enclosed (U and L shaped) houses. Moreover as compared to semi enclosed courtyards with a mean area of ~350 ft^2, fully enclosed courtyards had smaller area of ~180 ft^2. This significantly contributed towards making the indoors cooler and thus thermally comfortable as semi-enclosed houses had better airflow and ventilation due to the presence of partially open spaces. Other factors that contributed towards better airflow included large and spacious windows that had a mean area of 4-7 ft^2 allowing heat to dissipate efficiently and avoiding temperature buildup.

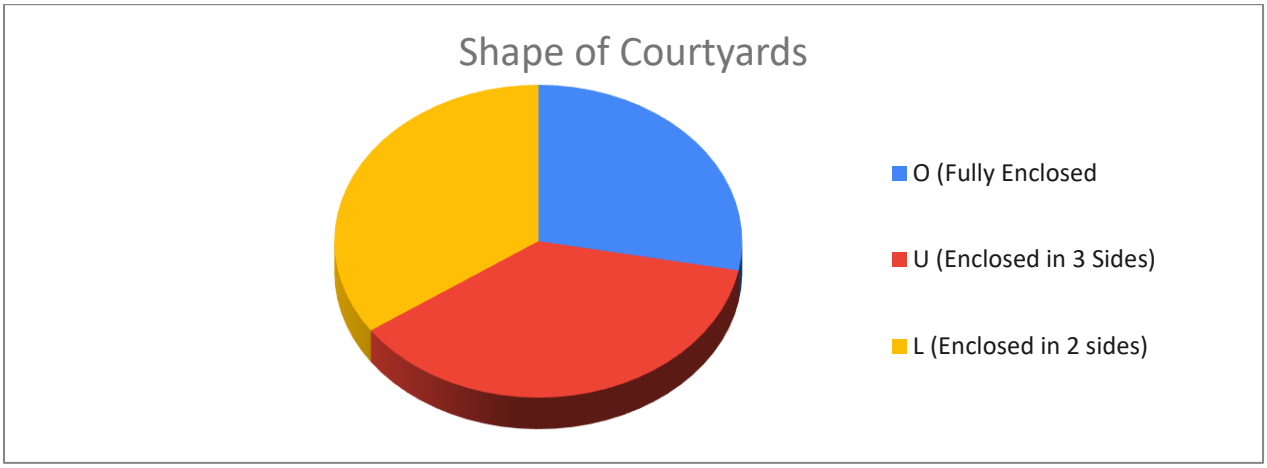


Fig.2. Shape of Courtyards Investigated During the Study

While examining the orientation or direction of houses, it was seen that 26% of the houses had courtyards at the northern part i.e. facing north-south, followed by those at eastern ends (23.33%) and Western ends (21.33%) as shown in Fig. 3. The north-south orientation is considered to be the most advantageous for thermoregulation [19]. The houses at eastern ends feel most of the heating discomfort in morning hours, between 0700 to 1100 am. The houses at the western end receive highest heat between 1400-17000 hours. Thermal discomfort during these hours is combated by architectural elements like bamboo carpets and covers, locally known as ‘paati’. Curtains made of airy and light materials are also used to give shading while allowing adequate airflow to thrive inside [20]. Mud houses in several areas are sprayed with water during the morning and noon hours of peak summer.

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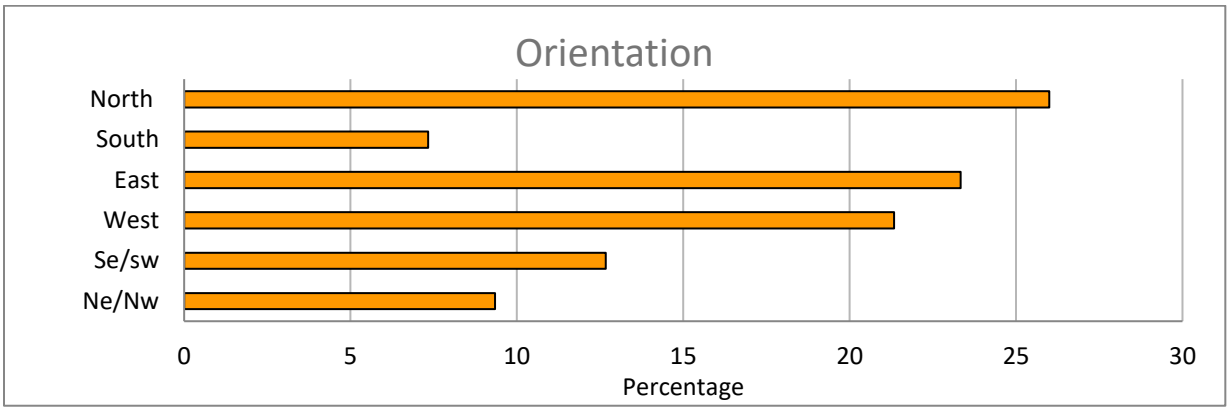


Fig.3. Orientation of Courtyards Investigated During the Study

The stilted bamboo houses of Tripura are fixed on bamboo stilts at a certain height above the ground. These houses have large doors and windows along with abundant shading in their courtyards. Of all the houses surveyed, it was found that 61.33% of people had shading in their courtyards, as shown in Fig.4. The artificial shading materials usually consisted of corrugated tin sheets or bamboo shades hand-woven together by the locals. Bamboo materials are known for bringing effective cooling to traditional houses [21-22]. The corrugated tin shadings had a length within a range of 8-14 ft and a breadth of 7-9 ft respectively whereas most Bamboo shadings had a mean area ~10.5ft^2. Natural shading like flora, including large species of trees, as for instance, *Mangifera indica*, *Syzygium cumini*, *Artocarpus heterophyllus*, and *Shorea robusta.* Tree shadings help in maintaining temperature in both urban as well as rural landscapes [23-24]. These strategies allow people to enjoy a comfortable stay even during summer times.

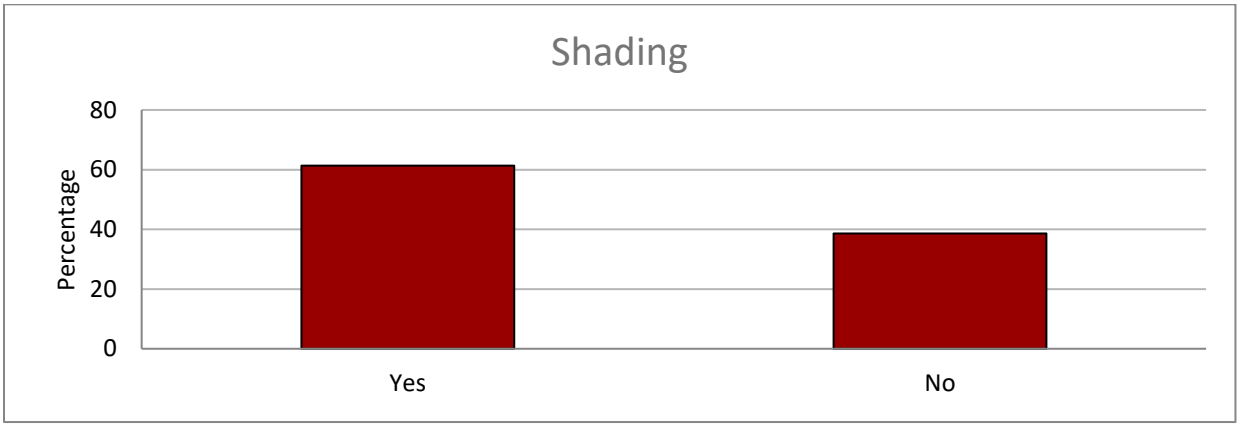


Fig.4. Shading Status in Courtyards Investigated During the Study

Natural elements like trees, presence of water bodies, within the courtyards can enhance thermal comfort of buildings by notably decreasing the PET (physiological equivalent temperature) by 2.1 ºC [25-26]. In the survey conducted, 25.33% of the participants had ponds situated in their courtyards. Other than this, 22.67% had various fruiting trees and 17.33% cultivated shrubby

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vegetation and flowering gardens in their courtyards as shown in Fig.5. The presence of numerous natural elements therefore acted as a shield against the muggy hot summers of the state.

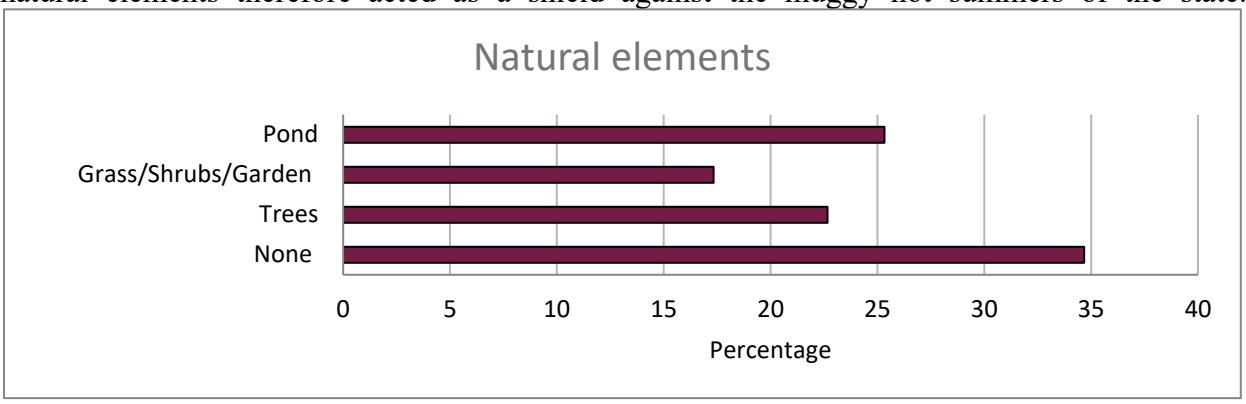
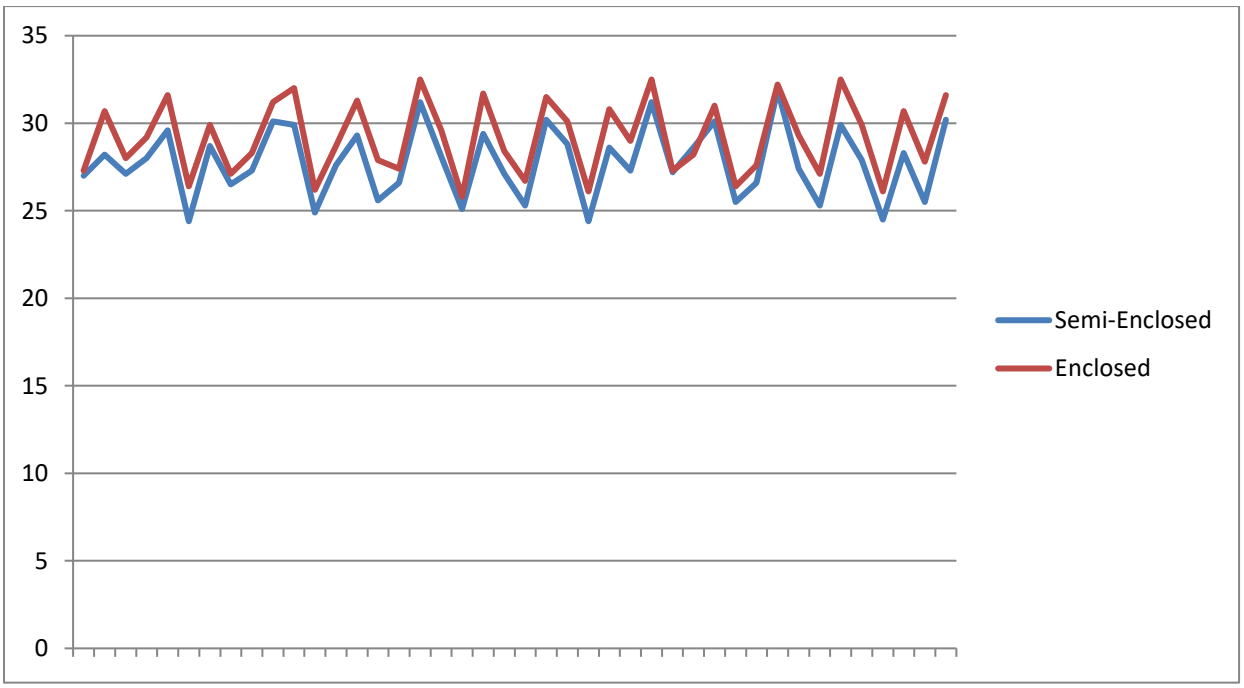


Fig.5. Presence of Natural Elements in Courtyards

Under this study, a temperature investigation was also conducted under which a comparative analysis was done for the temperatures of houses with semi-enclosed courtyards with that of enclosed courtyards. An average decline of temperatures were observed within a range of 0.3-2.5 ºC and along with an average decline of 1.4095ºC for semi enclosed courtyards when compared to fully enclosed ones as shown in Fig.6. This temperature difference can be attributed to more ventilation due to one side of the courtyard being open, that acts as drainage for hot and humid air and allows circulation, thereby dropping the temperatures down. Similar results can be seen in the studies that were carried out to assess the thermal performance of residences, where, higher values of temperatures are attributed to poor ventilation [27-28].



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Fig.6. Temperature Difference in Courtyards

Despite many similar research work done on hot arid regions [1,29-33], and a thorough analysis of the research available it has been found that there is no general framework available that lists out the major architectural characteristics and elements, required for the Cfa climate type as shown in Table.2. Hence this research also brings up a general framework that can be used for architecture of similar climate as that of the study site.

Table 2: General Framework for Courtyard Structure and elements in Cfa Climate.

1.Orientation and Layout: • Pre-planning courtyard design according to natural ventilation and shading sources. • Alignment of courtyard to capture prevailing winds for airflow • Preference of semi-enclosed courtyards over fully enclosed ones.
2. Shading and Natural Elements • Integrate diverse, natural, sustainable and durable shading materials like bamboo. • Incorporating greenery in the form of gardens or by planting trees • Presence of Ponds, fountains or other small water reservoirs to aid in evaporative cooling
3. Material Selection for Courtyard Surfaces • Use heat-reflective materials to minimize heat absorption • Utilize architectural features like louvers or adjustable openings that aligns with the weather and wind patterns and creates sustained air flow.
4.Ventilation and Airflow • Strategic placement of vents in most-used parts of the building. • Vents should be covered in meshwork to avoid unnecessary pest or insect entry. • Large windows with meshwork • Insulated glazing can be used as a layering of glass or similar materials in vents and windows.
5. Behavioral Adaptation • Educating inhabitants on the preferable temperature timings in alignment with local temperatures. • Encourage opening and closing of architectural elements like windows and vents according to requirement.
6.Maintenance and Upkeep • Regularly maintaining vegetation and shading structures for optimal functionality • Periodically assess existing architectural elements for replacing requirements.

Conclusion

Courtyards have been an integral part of architecture since ancient times. These enclosed or semi-enclosed spaces hold key significance in the thermoregulation of residences. Numerous researches have been done regarding climate-specific elements that courtyards can be equipped with, for better thermal comfort. However, there is a lack of literature and research particularly for the Cfa climate i.e humid subtropical climate on this topic. This paper conducts a thorough investigation in a state of northeastern India that is known for its predominantly Cfa climate. An open-ended survey was done and temperature readings were recorded to carry out a comprehensive analysis of the semi enclosed and fully enclosed courtyards of the region and it was found that the semi enclosed courtyards showed a decline in the average temperature levels throughout the day,

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reducing overall discomfort. The findings indicated several characteristics and elements that enhanced thermoregulation, acting as a catalyst, thus, and enhancing thermal comfort. These findings were utilized to draft a basic framework that has the capacity to be considered as a foundation for construction of buildings in similar climates. The abundance of bamboo-based shading systems along with natural elements' role in thermoregulation was also upheld during the study thereby promoting sustainability. Analysis of all these factors has been crucial to come up with an all-round study of the Cfa climate for the first time, while also setting up the stepping stone of more detailed investigation in the relevant field.

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Effect of multi-walled carbon nanotubes on crystallinity and fracture toughness in plasma-sprayed hydroxyapatite coatings

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Abstract

Hydroxyapatite (HA) coatings with less fracture durability and crystallinity increases bioresorption, which comes about in destitute attachment between the coating and substrate. This can be since HA coatings quickly lose bulk, which leads to destitute steadiness and inevitably extricating of inserts implant. Therefore, in the present work an attempt has been made to improve crystallinity and fracture toughness of HA coating reinforced with multiwalled carbon nanotubes (MCNT). Crystallinity and fracture durability of HA fortified with MCNT was observed to be better as compared to immaculate HA coat. This improvement is attributed to mechanical and thermal properties offered by MCNT. The analytical tools were used to examine the phase and microstructure of the coatings in the present work.

Keywords: Plasma-spray technique; Crystallinity; fracture toughness; XRD; tribo-test

Introduction

Hydroxyapatite (HA) is wordwide used in uncemented prosthesis [1-2]. HA is a bioactive substance that supports osseointegration and bone development that shares chemical similarities with human bones. Its use in orthopaedic load-bearing applications is motivated by its unique ability to cooperate with living tissues and to stimulate tissue formation on the metallic embedded surface [3]. HA bioceramic powder is applied to these metal surfaces. In the medical field, metallic materials coated with HA are typically utilized for implants[4]. Artificial implant-bone fractures early due to fast wear caused by brittleness and low fracture toughness of HA. Numerous studies have established that lower tribological properties is the cause of the deterioration and eventual failure of orthopedic implants. After 10 to 12 years of use, knee and hip implants start to degrade [5]. Adverse oxyhydroxyapatite, TCP, TTCP, and CaO stages have too been detailed within the published writing to emerge in HA coating when utilizing the thermal spray technique [6]. Because these phases dissolve in body fluids, they may cause implant instability. By carefully choosing process settings and specific bioceramic reinforcement during the plasma spray HA coating method, the formation of these phases can be minimized. By doing this, the crystalline index structure of the HA coating is improved, these phases are eliminated, and residual stresses are

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decreased [7]. Due to high melting point of HA, high temperatures have been used in the majority of HA prosthesis fabrication processes. The challenge with these tactics is managing HA detachment from other phases. Throughout these processes, high temperatures are applied to HA powder. The low crystalline structure results from the thermal breakdown of HA at these high temperatures into new phases [8].

In order to improve the mechanical characteristics of biometal substrates, various analysts have tested with an assortment of HA fortifications. ZrO_2, CNTs, TiO_2, and Al_2O_3 are the distinctive bioceramic fortifications [9]. In few studies it has been observed that the break sturdiness of bioceramic HA coatings is within the run of 0.4-1.1 ($MPa.m^{0.5}$), though the comparing esteem of common dense bone is within extend of 1.9-6 ($MPa.m^{0.5}$) [10]. A few researchers worked on aluminium oxide and carbon tubes reinforced HA which is coated on metal samples. Advancement in break durability was demonstrated within the sandwich coats [11]. Khanal et al. [12] too investigated on the half breed composites utilizing functionalized carbon tubes and nylon in HA coating.

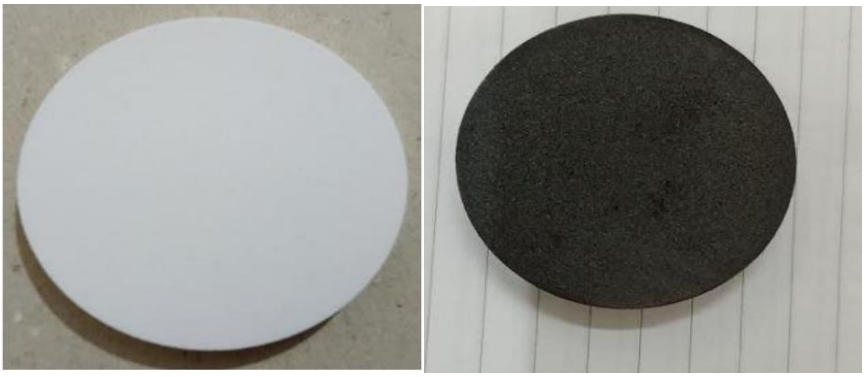
According to a detailed examination of the relevant reported literature, there has been no systematized research pertaining to manufacturing and characterisation of HA-MCNT coating on titanium samples. The present paper describes the development of a HA-MCNT coats with improved fracture resistance and high crystallinity on titanium substrates utilizing a plasma technique. After an extensive review of the literature, the scope of the problem and the goal of this study were defined. To produce high-quality HA-MCNT coated titanium material bio-implants, thorough research is needed. The current study is aimed at coating of titanium substrates with HA and HA fortified with 5% (by weight) MCNT) using plasma spray technique. The most effective parameters of the plasma spray method were used for coating onto the substrates. Post plasma spray coating, the coated substrates underwent standard procedure tests to determine their wear characteristics and fracture toughness. For every coated substrate, SEM pictures were captured both before and after the wear test.

Materials and Methods

Solid titanium metallic substrates were procured from Pradip Metal Ltd. located in Mumbai, India. The 40 mm diameter and 6 mm thick samples as per the standards were prepared using laser technology. Metallic substrates were first polished, and then they were ultrasonically cleaned with acetone. The cleaned samples were dried for ten hours at 750 ^{0}C in an air-circulated oven. For sample preparation, the ASTM G99-95a standard was adhered to. The crushed and sintered HA powder with a Ca/P ratio of 1.66, crystallinity greater than 99%, and phase purity greater than 99% was utilized as the feedstock. HA satisfies the standards of ISO 13779-6, a global standard. The metallic samples were grit blasted at 3-5 bar blasting pressure prior to HA coating on metallic substrates in order to improve the binding between the metallic sample and the HA coating. To create a composite powder or powder precursor, 5% weight percent of MCNT (97% purity, 30-50 nm OD, 0.5-2.2 μm in length, density-1.9 g/cm^3, BARC, Mumbai) was combined with sintering

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HA powder (particle size 40–60 μm) in a ball mill. The industrials plasma spray gun was utilised to create HA and HA-MCNT coats on metal samples. Table 1 shows the input parameters for the plasma coat. Figure 1(a) and 1(b) show photographs of an HA and HA-MCNT coated specimen.



(a) (b)

Fig.1. (a) HA Coating; (b) HA-MCNT Coating.

The sprayed samples were analysed using FE-SEM for microstructure characterization of the coatings. XRD analytical tool was used to assess the physical state of HA and plasma coatings on titanium. Equation 1 is then used to get the % crystallinity [13].

$$\%\ Crystallinity = \left[\frac{\Sigma Ac}{\Sigma(Ac+Aa)}\right] \times 100 \quad (1)$$

Where ΣAc is the sum of HA crystalline peaks and ΣAa is the sum of amorphous peak.

The fracture toughness of coatings was determined by using the Anstis equation [14].

$$k_{IC} = 0.016 \left(\frac{E}{H}\right)^{0.5} \frac{P}{C^{1.5}} \quad (2)$$

Where k_{IC} – Fracture durability, E- Flexible modulus, H-coat hardness, P – Connected stack/weight and c- Spiral crack propagation.

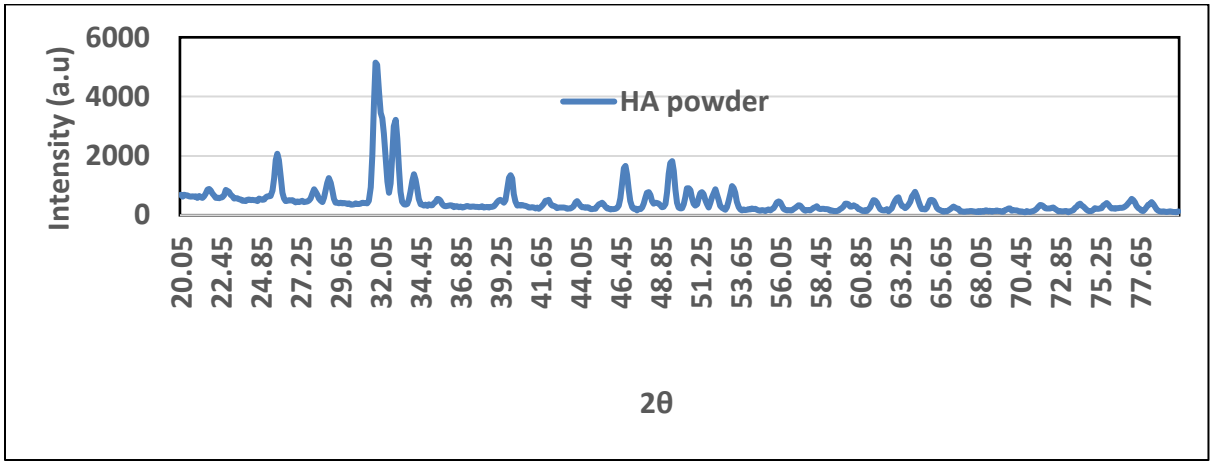
Results and Discussion

Table 1. Process parameters.

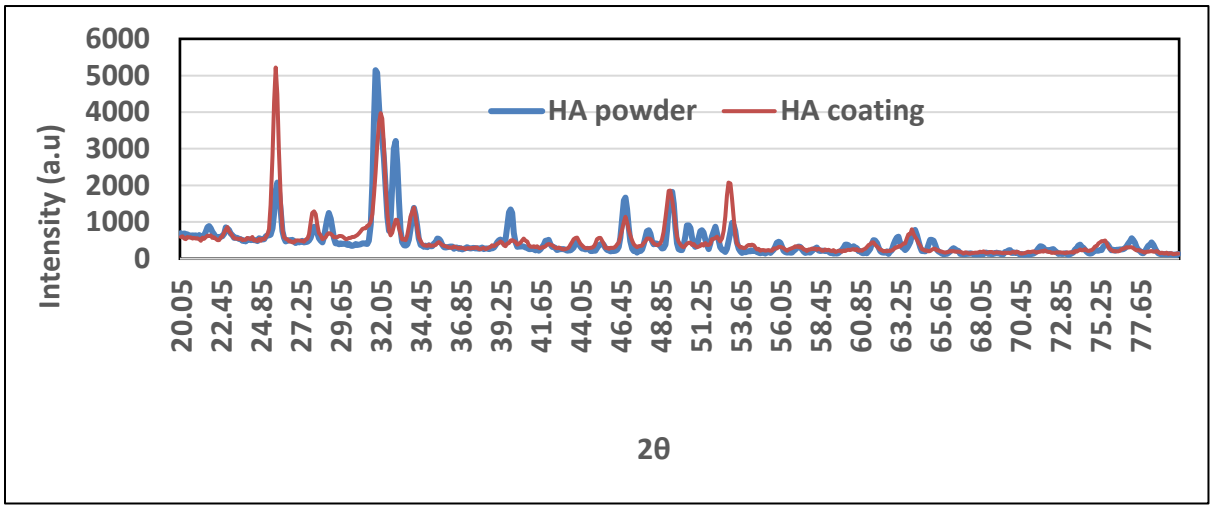
Sr. No.	Process Input	Value
1	DC power	25-28 KW
2	Primary and Secondary gas	Argon
3	Flow rate	08-10g/min
4	SOD	230 mm
5	Traverse velocity	38 -46 mm/s

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Figures 2(a, b, c) shows the XRD spectra of bio-ceramic HA powder, as well as a comparison of the XRD designs of HA powder, HA coating, and HA-MCNT coatings. Crystalline crests were compared with JCPDS cards and were observed similar to JCPDS cards. The % crystallinity is calculated using data generated during the XRD characterization.

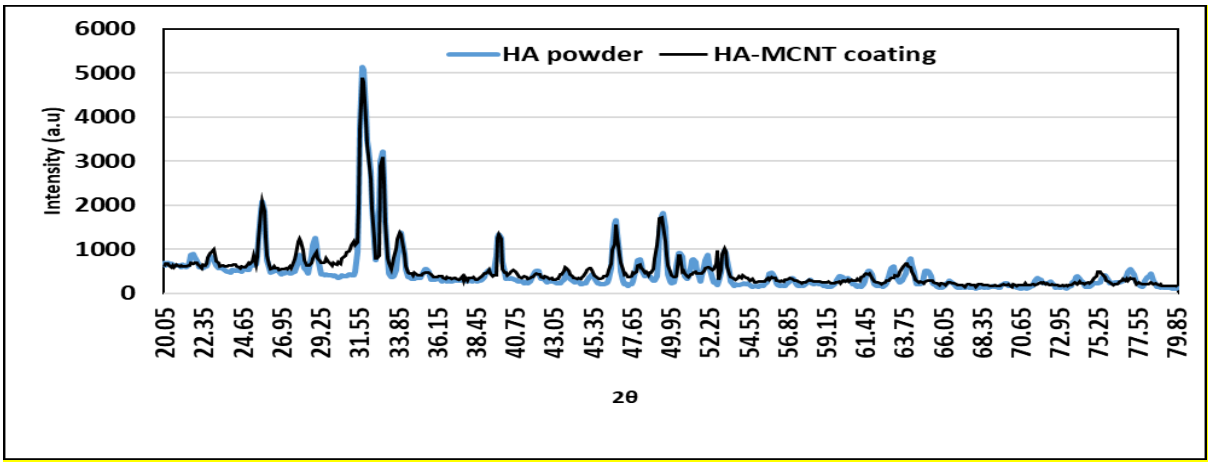


(a)



(b)

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(c)

Fig. 2. XRD (a) HA powder; (b) HA powder and HA coat; (c) HA powder and HA-MCNT coat.

In the thermal spray coating process, HA is exposed to higher heat zone than its melting point (~1200°C). Due to this, XRD peak intensity for HA coating at different 2 theta values showed expand and shrink peaks compared to pure HA biocermic powder. This behaviour ascribed to the formation of secondary phases in coatings like TTCP, TCP, and CaO. These secondary/amorphous phases are unsuitable for implant coating in orthopaedic applications. The formation of secondary/amorphous phases leads to the degradation and loosening of the implant in the in-vivo environment when it comes into contact with in-vivo body fluid. This causes implant failure.

By reinforcing the 5% MCNT in HA powder results demonstrated the similar peak intensity traces like HA powder. This might be due to the thermal disintegration properties of MCNT. In heat zones of plasma spray, when mixed powders are exposed to high flume, the maximum heat is carried or absorbed by the MCNT powder instead of the HA powder due to its inherent conductivity and heat capacity. These properties and behaviours of MCNT avoid the formation of an unfavourable secondary/amorphous phases in the HA-MCNT coating. Higher the formation secondary phases weaker the coating-substrate interface. Weaker the coating-substrate interface lesser the crystallinity index of artificial implant [3].

The crystallinity index of HA-coated substrates ranged between ~78%, while that of HA-MCNT coated substrates ranged between ~ 93%. The percentage index was calculated with the help of data generated in the Excel sheet during the XRD analysis with the help of a spectrometer. Ten measurements were taken for each coating sample and average index value was recorded for each crystalline index. The improved index in the HA-MCNT coating is attributed to maintaining a strategic distance from the arrangement of troublesome secondary or amorphous stages within the coating due to MCNT powder. As already shown, a diminish in crystallinity quickens the

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debasement of the HA coating in vivo. In vivo dissolving is undesirable since it leads in a weaker coating that's incapable to secure the embed over time, coming about in embed disappointment. Figure 3 shows the % crystallinity index of HA and HA-MCNT coating.

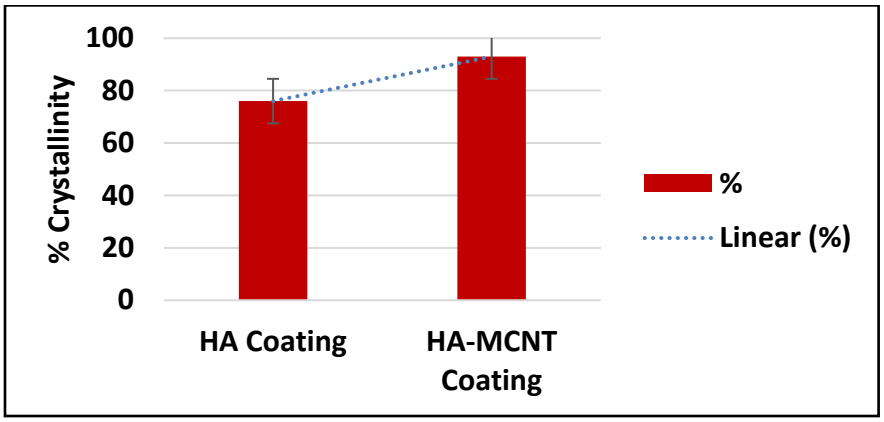
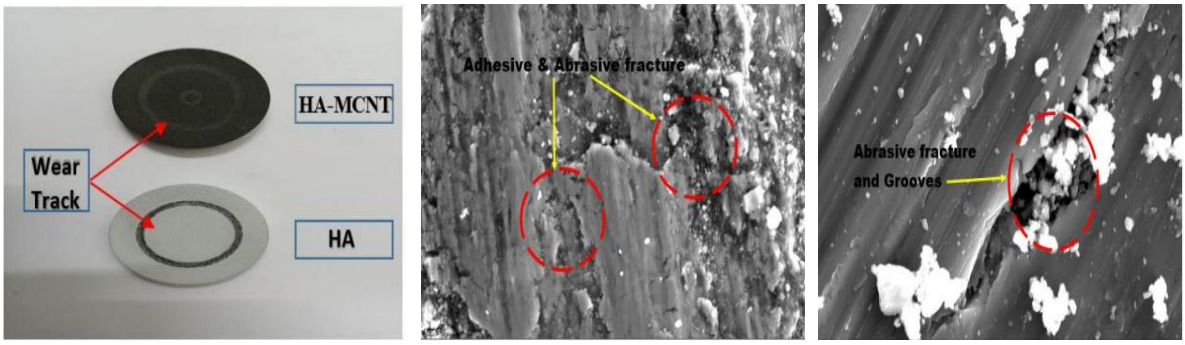


Fig. 3. % crystallinity of HA and HA-MCNT coating.

The occurrence of radial cracks and wear tracks in HA coat were observed to be greater in comparison to those in HA-MCNT coatings. There was a significant improvement in coating cracking performance as a result of the decrease in average radial crack propogation and enhance wear strength.The high aspect ratio quality of MCNT introduced the crack deflection and self-stretch power mechanisms in the HA-MCNT coating [15]. These two toughen mechanisms aid in enhancing the cracking resistance of HA-MCNT coats.

With reference to SEM image as shown in figure 5, it is observed that by reinforcing the MCNT in HA powder, the MCNT acts as a connector to hold the HA splats. In some places of coatings, it's like a bridge between HA splats. These types of roles of MCNT in the coating avoid and prevent the separation of HA splats from each other. This mechanism improves the wear resistance of the coatings. The micrographs of different coatings after the wear test are shown in figure 4 below.

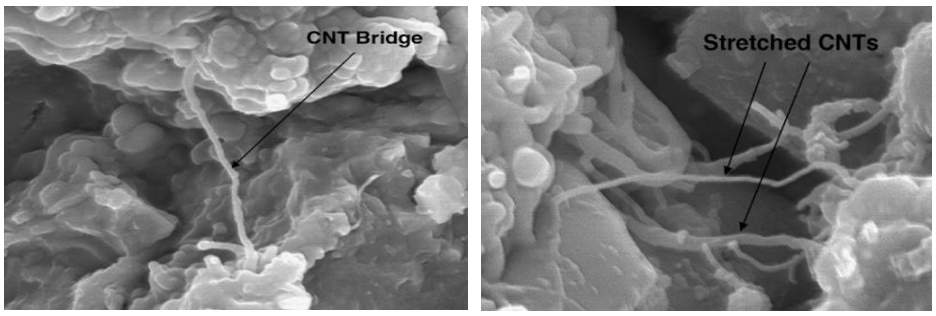


(a) (b) (c)

Fig. 4. Wear track (a) HA and HA-MCNT coat (b) HA coat (c) HA-MCNT coat.

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For HA-MCNT coat samples, the average fracture toughness was determined to be ~3.38 (MPa.m$^{0.5}$). These obtained values fall within the normal range for cortical bone seen in nature. The MCNT reinforcements, which serve as connector/splat bridges and prevent neighboring splats from separating, are responsible for the decreased wear rate and increased crack toughness of the plasma sprayed HA-MCNT coat. Researchers have shown that CNTs offer lubricating conditions during intense abrasion [15-17].



(a) (b)

Fig. 5. (a);(b) HA-MCNT coating reflects MCNT connector between splats.

Conclusions

XRD analysis revealed that HA-MCNT coating has more crystalline structure than HA coating. The addition of 5% (by weight) MCNT in HA increased the fracture toughness of HA coatings substantially. The average wear resistance also increased significantly when MCNT was added to HA. Microstructural studies of HA-MCNT produced coatings show that MCNT reinforcement has the potential to improve tribo-mechanical properties of HA. As a result, Therefore, MCNT has arisen as a likely support for HA to settle difficulties of crack sturdiness and wear opposition.

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Earlier Prediction of brain tumour through optimization algorithm for feature Enhancement and Measurement

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Abstract

Brain tumor detection of paramount importance for better patient outcomes. Conventional diagnostic techniques like magnetic resonance imaging (MRI) and computed tomography (CT) scans are widely employed for brain tumor detection. However, these methods can be both expensive and time-intensive, with their accuracy contingent on tumor size and location. FOA is a bio-inspired optimization algorithm inspired by the luminous patterns of fireflies, designed to solve intricate optimization problems. In this investigation, FOA is harnessed to optimize the feature selection process for identifying brain tumors through medical imaging data. The proposed methodology encompasses medical image preprocessing, feature extraction, and the application of FOA for the selection of the most informative features. These selected features are then employed in a machine learning classifier to distinguish between tumor and non-tumor cases, with the primary aim of enhancing overall accuracy, sensitivity, and specificity in brain tumor detection, particularly in the case of smaller or challenging-to-detect tumors. To assess the efficacy of this novel approach, extensive experiments were conducted using a diverse dataset of brain images. The results clearly illustrate that the amalgamation of FOA-based feature selection and machine learning classifiers substantially augments early brain tumor detection compared to conventional methods. This approach holds considerable promise for reducing false negatives and false positives, potentially leading to improved patient outcomes and healthcare cost savings. In conclusion, the utilization of the Firefly Optimization Algorithm in brain tumor detection presents a promising avenue for advancing early diagnosis and treatment results. This research contributes to the domain of medical image analysis and underscores the potential for optimizing the feature selection process to amplify the precision of brain tumor detection.

Keywords

Firefly optimization , Convolution method , tumor detection and feature extraction

Introduction

By 2023 Brain tumors pose serious health hazards and dramatically reduce a patient's quality of life. They rise annually. Even yet, a timely and precise diagnosis is still required for a treatment to be successful [1]. The accuracy and effectiveness of the traditional techniques used to evaluate risk, divide, and classify brain tumors are, nevertheless, limited. Deep learning-based models are

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starting to be used in medical imaging analysis, which offers a promising way to greatly increase the effectiveness and accuracy of brain tumor identification [2]. Although they have great potential, obstacles to their widespread implementation include data quality, computational complexity, interpretability, and smooth integration into clinical procedures [3]. Thus, there is a pressing need for a sophisticated deep learning model that can handle brain tumor segmentation, classification, and risk assessment efficiently. To ensure that patients with brain tumors receive effective treatment in a timely manner, it should also be readily scaled, interpretable, and integrated into clinical processes. This inquiry was driven by a few things. Improved early diagnosis and precise classification of brain tumors can significantly improve patient outcomes and quality of life. Moreover, it is critical to develop ever more intricate models that support a range of tumor shapes. The wider application of these models in clinical contexts also requires lower processing costs [4]. The prediction of patient outcomes and survival rates can have a significant influence on customized treatment regimens. The majority of the research depends on The Brain Tumor Segmentation dataset serves as the investigation's main source of data [5]. which offers a range of multimodal MRI images used for tumor identification, classification, and detection. This dataset offers standardized, high-quality, anonymous data that is perfect for deep learning model training. It has many MRI modalities, each of which adds unique tumor features for a thorough examination. An advanced multimodal diagnostic model based on deep learning is made possible by expert annotations present in the dataset, which enable intricate multiclass segmentation tasks [6]. The principal aim is to create a multimodal diagnostic model for brain tumor analysis that is based on deep learning and includes segmentation, classification, and risk assessment. In order to extract comprehensive features, this model will integrate different imaging approaches. Sophisticated preprocessing techniques like CNMF [7] will deal with variances in imaging modalities and problems with data quality. DBT-CNN will be used for comprehensive classification, while complex algorithms like RU-Net2 will be utilized for precise segmentation. Potential outcomes can be anticipated through the use of risk prediction algorithms such as logistic regression and the multivariate Cox model.

Related work

Utilizing its proficiency in brain tumor segmentation alongside the Inception ResnetV2 model, the Adaptive Eroded Deep Convolutional Neural Network (AEDCNN) effectively distinguishes between benign and malignant brain tumors, boasting impressive accuracy rates of 97.89% and 93.27%, respectively [9]. This distinction extends to meningioma, glioma, and pituitary brain areas, showcasing its precision. Another innovative model, the Nature-inspired ResNet 152 Transfer Learning combined with a deep convolutional neural network (CNN) (Hyb-DCNN-ResNet 152 TL), reports high diagnostic and classification accuracies ranging from 94.31% to 99.57% [9]. Its success stems from employing various classifiers, threshold segmentation, and the watershed approach, achieving a remarkable 90% accuracy in tumor classification [10]. By employing a technique outlined in [11], this method divides the tumor area and accurately categorizes tumors as benign or malignant, achieving a tumor prediction accuracy of 91.718%.Furthermore, detailed in [12], Promising findings of 0.57 accuracy for survival prediction and 0.82 for dice scoring in tumor segmentation are obtained by using a DenseNet model for

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survival prediction and an ensemble of asymmetric U-Net-like structures for tumor segmentation. The Triple-Intersecting U-Net (TIU-Net), presented in [13], pushes the limits of segmentation and classification accuracy by combining binary-class segmentation U-Net (BU-Net) with multi-class segmentation U-Net (MU-Net) to achieve cutting-edge performance. Furthermore, as mentioned in [14],To obtain improved accuracy in tumor segmentation and classification, this method makes use of the weighted fuzzy clustering algorithm, the barnacle mating algorithm (BMOA), a random forest (RF) classifier, and deep auto-encoder (DAE) techniques. This method, which is based on [15], uses the Whale Optimization Algorithm (WOA) to improve the multilayer perceptron (MLP) classifier's parameters and achieve high classification accuracy for brain tumors. Moreover, initially proposed in [16], this approach establishes top-tier performance across multiple datasets by employing a 3D CNN for tumor segmentation, a hybrid method for survival prediction, and a 3D context-aware deep learning model for subtype classification. Furthermore, highlighted in [11], this method's utilization of a CNN for brain tumor prediction showcases exceptional accuracy on the BRATS 2015 dataset. Additionally, our method, showcased in [17], combines radiomic features, machine learning algorithms, and MRI images, resulting in a striking 95% accuracy rate in predicting the survival of patients with glioblastoma. Described comprehensively in [19], this technique segments tumors from MRI images using a CNN and achieves a 91% segmentation accuracy on the BraTS 2017 dataset. Finally, our approach predicts patient survival for both adult and juvenile brain cancers, leveraging histopathological images and gene expression patterns. When tested on two patient groups, the accuracy reached 75% for pediatric patients and 82% for adult patients.

Methodology

The intricate brain governs multiple functions like cognition, sensation, memory, emotions, motor skills, and perception, significantly influencing human existence. Even minor damage, illness, or disorders impacting the brain can deeply affect an individual's life. Specific issues give rise to various diseases and disorders of the brain and nervous system. Early diagnosis of these conditions holds paramount importance due to the brain's complexity, making advanced stage diagnosis and treatment notably challenging. Notably, certain brain diseases are more commonly observed.

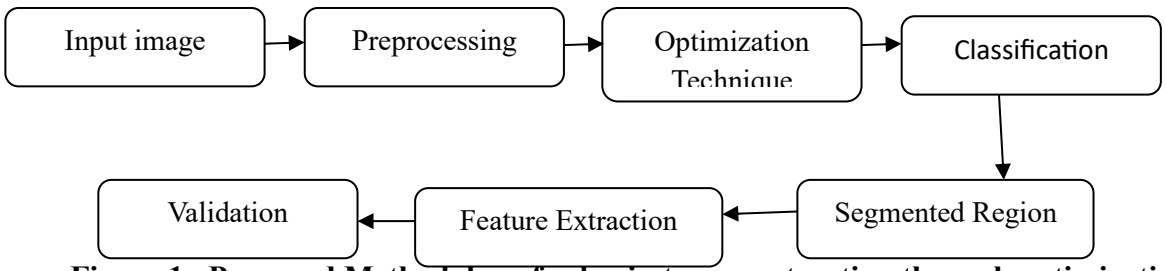


Figure 1 . Proposed Methodology for brain tumor extraction through optimization process.

An abnormal mass that forms inside the brain as a result of aberrant cell action is called a brain tumor. There are many different kinds of these tumors, however they are primarily

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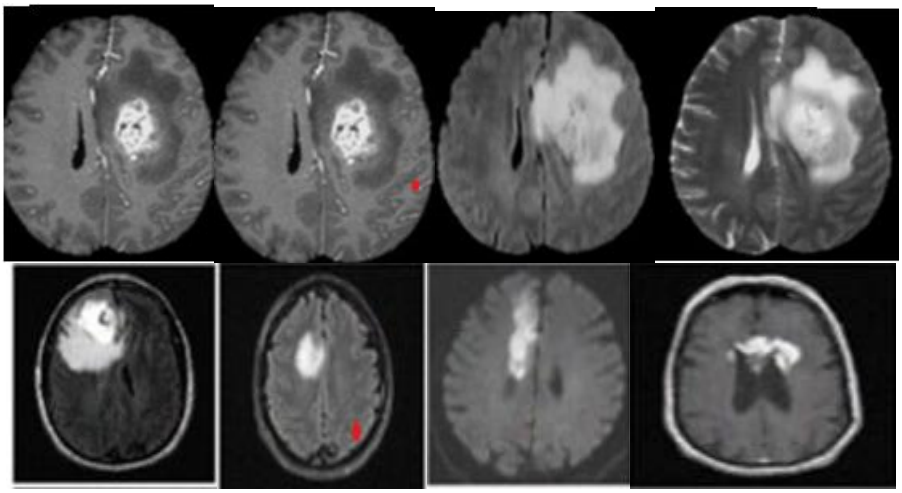
categorized as malignant (cancerous) or benign (non-cancerous). They can also be divided into two groups based on where they originated: either from the brain itself (primary) or from other regions of the body (metastatic). Growth pace, location, and other factors can have a substantial impact on how brain tumors form and disrupt brain function. Depending on factors including tumor size, nature, and location, a patient's life depends on the timely and precise diagnosis of malignant tumors. But accurate tumor localization and segmentation are often difficult tasks for conventional techniques. A suggested computer-aided diagnostic paradigm seeks to properly identify, segment, and categorize in order to meet this difficulty.

Study Area

We took advantage of the publicly accessible BraTS dataset, which was created especially to study brain tumors using multimodal MRI scans. We employed BRATS sets from [40], [21], [22], [23], and [40] in this investigation. It is well known that BRATS collections work well in deep learning applications. The two primary forms of brain cancer, High-Grade Glioma (HGG) and Low-Grade Glioma (LGG), are covered in these databases. Tissue transverse relaxation time (T2), tissue contrast (T1C), and tissue - longitudinal relaxation time (T1) the four distinct MRI scan modes include FLAIR (fluid attenuation recovery) and others. We used 70% of the data for training, 10% for validation, and 20% for testing during our research. Extensive dataset details are given in Table 2, and sample MRI scans from the BraTS data set are displayed in Figure 3. Because they incorporate a range of characteristics of brain tumors using multimodal MRI imaging, the most recent editions of the BraTS dataset are an essential tool for research on brain tumors.

Result and Discussion

Using the BraTS dataset, we thoroughly assess a number of deep learning models—including a recently developed one—with an emphasis on how well they classify brain tumors. In addition, we carry out a comparative study using a baseline model to demonstrate the progress made in this area.



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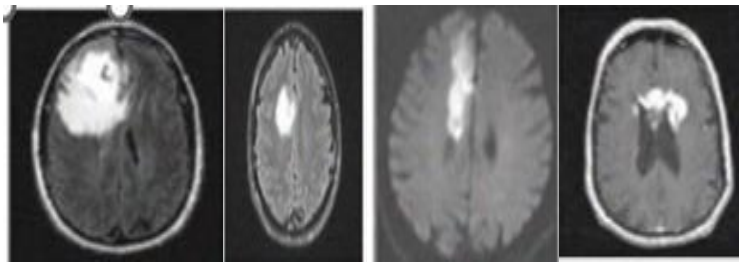


Figure 1. shows optimization algorithm for brain tumor

Image pre-processing, which is necessary because of the noise, distortions, and intensity variations in the images, is the initial step in the interpretation of medical images. The main focus of this work is brain MRI scans, which need careful pre-processing to handle. Experts in picture contrast features must have a thorough comprehension of the brain information represented in the intensity fluctuation of magnetic resonance imaging data. The fact that medical scans are generated by a variety of magnetic resonance movements makes it difficult to control them consistently. Over time, the same tissues experience noticeable intensity changes due to bias field distortion. Thus, one of the most important steps in the analysis of medical images is preprocessing picture intensity [24]. The study's MRI scans were taken from the BraTS dataset using particular preprocessing methods. As part of our process, we used the Convolutional Normalized Mean Filter (CNMF), which is well known for its ability to blur images without sacrificing their edges. A normalized mean filter and a convolutional filter make up CNMF [25]. One notable and important limitation of the Normalized Mean Filter (NMF) is that it overlooks local features like noise level and edges while removing noise. The proposed CNMF overcomes this problem by implementing intricate processes. By applying a convolutional filter to the entire image, CNMF replaces noisy pixels while accounting for all of the information contained in the image. Improving image quality without sacrificing the original image data is its main objective. This method replaces the deformed pixels with the convolved median value of the original image. The operations of CNMF are represented mathematically as follows:

$$cmi = conv.median[In-1|i \in K \cdot W] \quad (1)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

In equation (1), the term "cmi" refers to the convolved median value. The process of obtaining this value involves iterating through the image sequence (In−1) and performing the dot product operation between the window size (W) and the convolutional kernel (K).The Firefly Optimization Algorithm (COA) is an approach that simulates the hunting behavior of fireflies and is used to solve complicated optimization problems in a range of disciplines, including computer science, economics, and engineering. Similar to genetic algorithms and particle swarm optimization, which draw inspiration from nature, the concepts behind COA are developed via observing the behavior of cats. COA optimization problem solutions are likened to a pack of "cats." The algorithm mimics the actions of cats, such as scouting out potential prey (optimal solutions), exploring their environment, and exchanging information with other community members. These steps lead to the development of mathematical formulas and rules that guide the hunt for the perfect or nearly perfect solution.Iterations are a crucial part of the COA algorithm. During these rounds, the "cats"

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(i.e., potential fixes) navigate a search space, mimicking the phases of discovery and development.The cats are always moving toward better solutions, guided by fitness functions, and changing where they are. This is similar to how cats would hunt in the wild.COA is utilized for optimization issues, much like other metaheuristic algorithms, particularly when it comes to effectively exploring solution spaces. It excels in challenging scenarios where conventional algorithms may struggle to find the optimal solutions.

Table 1. shows the image characteristics and brain tumor classification

Tumor Type→ Performance Measure (%) ↓	CSO				HOG (CSO)			
	neurosis	edema	noise	Noise enhance	neurosis	edema	noise	Noise enhance
Accuracy	73.12	80.12	85.12	91.12	63.12	70.12	80.12	90.12
precision	75.12	81.12	86.12	90.12	65.12	74.12	85.12	91.23
F measure	76.15	82.23	86.14	90.36	65.15	78.15	84.55	95.63
entropy	74.15	82.36	86.12	90.14	68.12	75.16	84.32	95.63
Sensitivity	78.12	83.23	87.12	90.56	67.12	75.32	86.12	94.23
selectivity	72.33	84.23	89.16	90.45	69.12	75.96	87.12	95.12

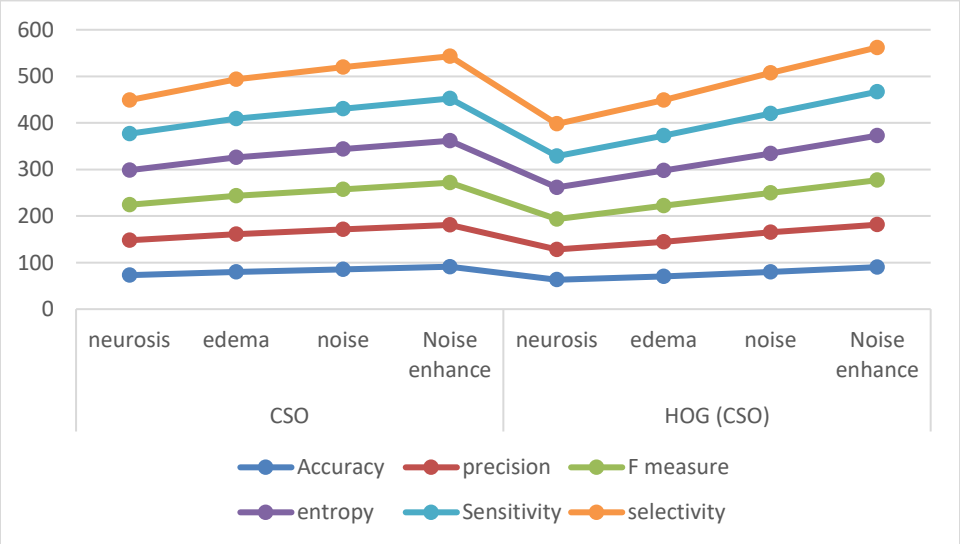


Figure 2 . statistical analysis of Brain tumor detection

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Conclusion

Through our study, we propose a comprehensive deep learning architecture to improve brain tumor diagnosis. Our main goals are to produce accurate survival rate estimations, increase classification accuracy, and accomplish exact tumor segmentation in order to optimize treatment procedures. During the pre-processing phase, we use CSo and FOA) to enhance the data quality. We employ the new DBT-CNN model for classification and the RU-Net2 model for tumor segmentation once the dataset has been cleaned up. To extract characteristics from the Cox model and produce logistic regression estimates of survival rates, this segmentation phase is necessary. Our method outperforms current alternatives in accuracy while drastically reducing processing requirements.

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CPU Performance in Container and Virtual Machine: a comparative Study

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Abstract

Containerization and virtualization are widely used technologies in cloud computing environments for workload management and resource allocation. The migration of containers and virtual machines (VMs) across different hosts or clusters is a crucial operation to ensure efficient resource utilization and workload balancing. This research aims to analyze the CPU performance of container and VM during migration and startup time to understand their impact on system performance and identify potential bottlenecks and hence conclude that CPU time to startup a container is less compared to CPU time required for the VM.

Keywords: CPU performance, containerization, virtualization, migration, cloud computing, workload management, resource allocation.

I. Introduction

Containers and virtual machine (VM) live migration are two popular technologies used in cloud computing and virtualization. An application container is an isolated, lightweight environment for running applications and their dependencies. Developers can build applications that run seamlessly across different computing environments with their help, since these technologies provide a consistent, portable way of packaging and deploying software. [10] Containers share the host operating system's kernel, which makes them more efficient and lightweight compared to traditional VMs. On the other hand, VMs are virtualized instances of a complete operating system and its associated applications. They provide a higher level of isolation and security compared to containers, as they run on a hypervisor that emulates the underlying hardware. VMs are more resource-intensive compared to containers, as they require a dedicated operating system for each instance.

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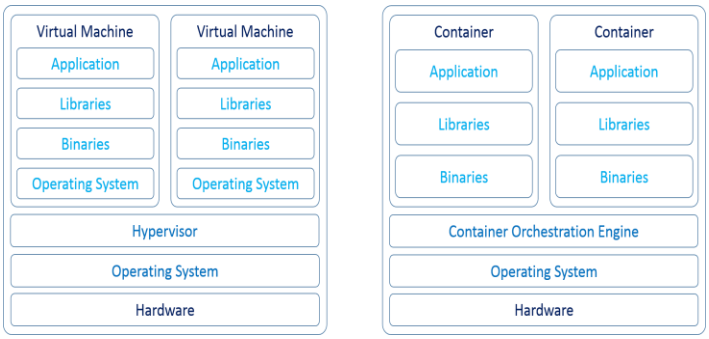


Figure 1: Virtual Machine vs Container

The Fig(1) shows a Virtual machine and container , Live migration is a technique used to migrate containers or Virtual machines between the physical hosts without interrupting their operation. Moreover, migration helps to balance workloads, maintain hardware, and recover from disasters. [6] Live migration also ensures that the application continues to run without any noticeable downtime because the state of the container or virtual machine is transferred from the source host to the destination host. During container live migration, the container's state, including its running processes and network connections, is transferred to the destination host. [9] As part of the migration process, the container runtime ensures that the application remains available during the migration. A VM live migration involves moving the entire VM state, including its operating system, applications, and memory contents, to the destination host. VMs continue to run uninterrupted during migration because the hypervisor manages the process. In addition to balancing workloads, improving resource utilization, and increasing availability, containers and VMs offer live migration benefits [13]. Comparatively to VMs, containers provide faster migration times and require fewer resources. A VM, on the other hand, provides greater isolation and security, making it suitable for running legacy applications or workloads that need to comply with strict regulations [13].

In this study, we examine the effects of CPU Performance during container migration between virtual machines and time taken for VM and container to start in terms of the following factors:

1. Start-up time: the time required start and run by VM and Containers are compared.
2. Latency: Measuring the time taken for migration, including the downtime experienced by the migrated workload.
3. Scalability: Assessing the performance of CPU-intensive workloads during migration under different load conditions.

To obtain comprehensive results, multiple scenarios will be considered, including varying workload sizes, and number of virtual machines. The obtained data will be analyzed using statistical techniques to identify trends, patterns, and potential performance bottlenecks. The outcomes of this research will contribute to a improved understanding of CPU performance implications of container and VM migration. The findings can aid cloud administrators and system designers in making informed decisions regarding workload migration strategies, resource

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allocation, and system optimization. Furthermore, the container suitability can be determined through a study or VMs for specific use cases based on their CPU performance characteristics during migration.

II. Literature Review

S. Ramanathan (2021) the study is based on network components in container environment and also compares with Virtual Machine environment. Thomas Wang et.al (2021) proposed an algorithm that considers dynamic scaling of the CPU usage for different resources and hence achieved better performances than compared algorithms. Tuan Le et.al (2020) the author surveys different methods for live virtual machine migration and considers merits and demerits of different techniques. Zhang et.al (2020) a study is made by studying Virtual machine migrations, the Virtual Machines are grouped based on a common factor and the comparisons are made between containers, where they are considered as processes in the virtual machines. Aditya Bhardwaj et.al (2019) in their work have setup LXD/CR container migration and hence reduced CPU usage, migration cost and in addition has improved performances over Virtual Machine pre-copy migration method.

Qi Zhang et.al (2018) a spark application of different configurations was used to set up environment to check the cpu usage of Virtual machines and Containers in a big data environment. Hence concluded that containers are easy to deploy than virtual machines. Prateek Sharma et.al (2016) did a comparative study on different virtualization technologies used for Virtual machines and Containers is done and the study is observed under different applications and different loads and conclude that the behavior of containers and Virtual Machines differed for different applications. Prashant Desai (2016) did a survey on performance comparisons of containers and virtual machines with different virtualization technologies and hence conclude that both virtual machines and containers behave differently for different parameters and the CPU performance of docker is better when compared to virtual machines.

III. System Model:

This section gives a brief of system model used in experiment setup The system model consists of 4 workers (VMs) which are created under a single real-time host server. Each worker machine has guest os as Centos8 with 2GB RAM and 2 CORE processor. The workers (VMs) are created using ansible tool that uses KVM for virtualization. The containers can be migrated among the workers manually. In the experiment the containers are assigned randomly and migrated manually to check the CPU usage.

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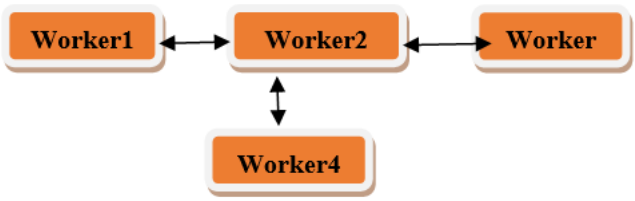


Figure2: System model

IV. Experiment Set Up:

Table1: Characteristics of system model

Cloud Server	**IBM Power 9**
VM (04) Operating System and VM configuration	Each Centos 7, 2GB RAM, 2 CORE, Each VM is labelled as worker 1 to Worker 4
Hypervisor	KVM
Containers	4 Containers each of size 35mb

There are four virtual machines installed on the cloud server with spawning one container each, the cloud server is a real-time server. The experiment is conducted to analyze the CPU performance and VM's and Container start up time during migration.

V. Results and analysis:

The purpose of this section is to present the results obtained, together with a discussion of what the results indicate.

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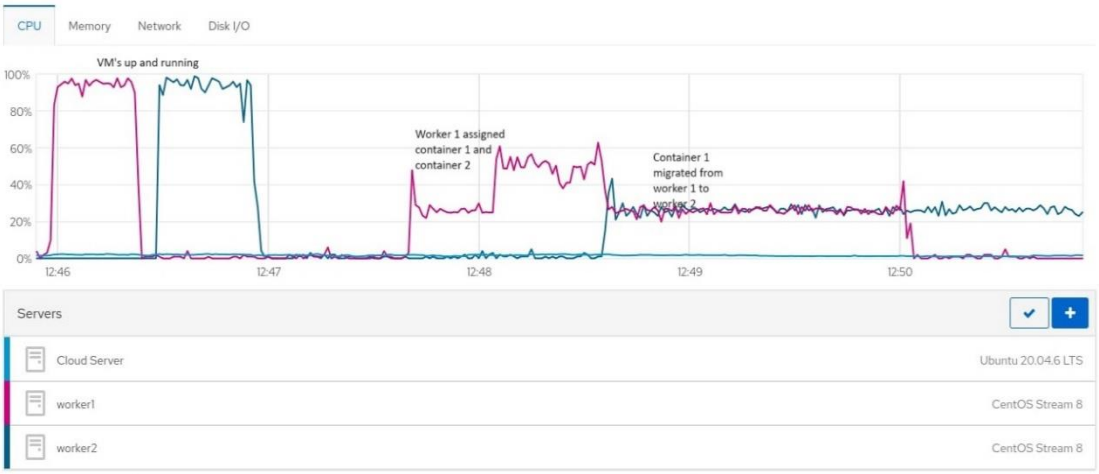


Figure3: Shows 2 VM's with container migration

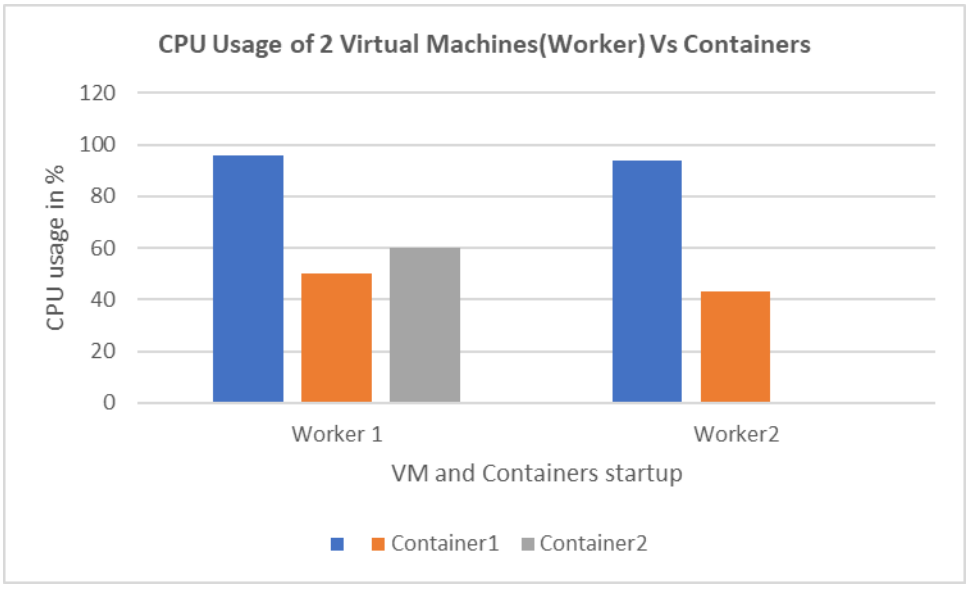


Figure4: Shows CPU usage required to start containers and VMs

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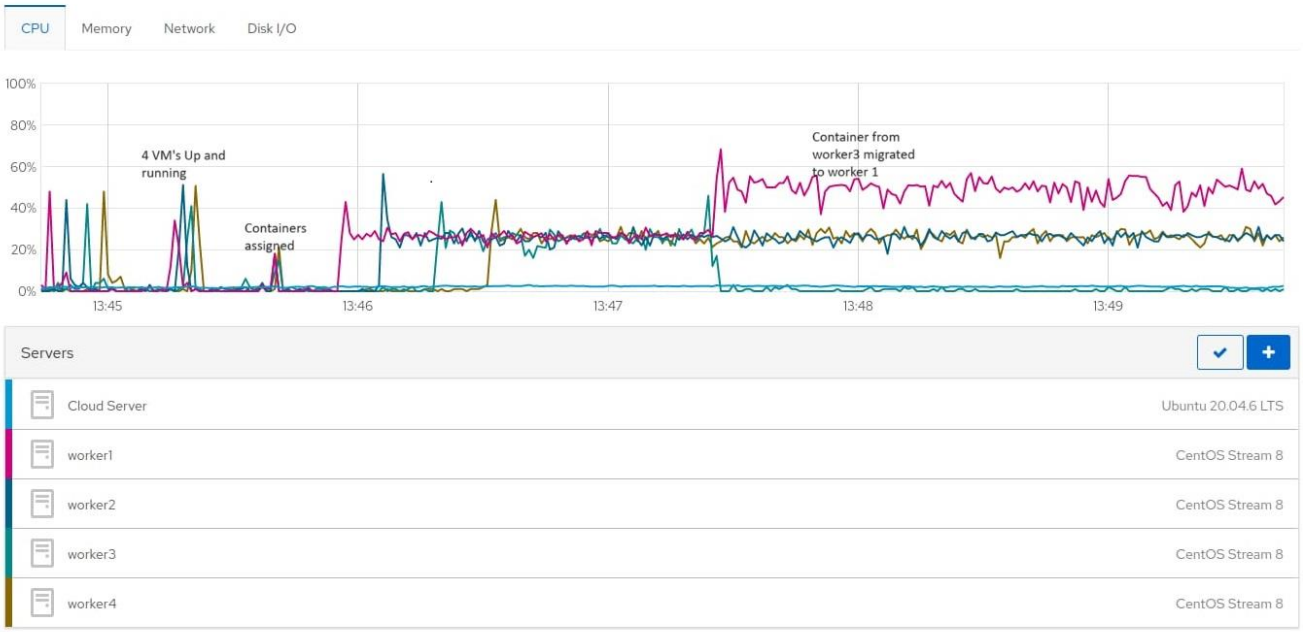


Figure 5: Shows 4 VM's with container migration

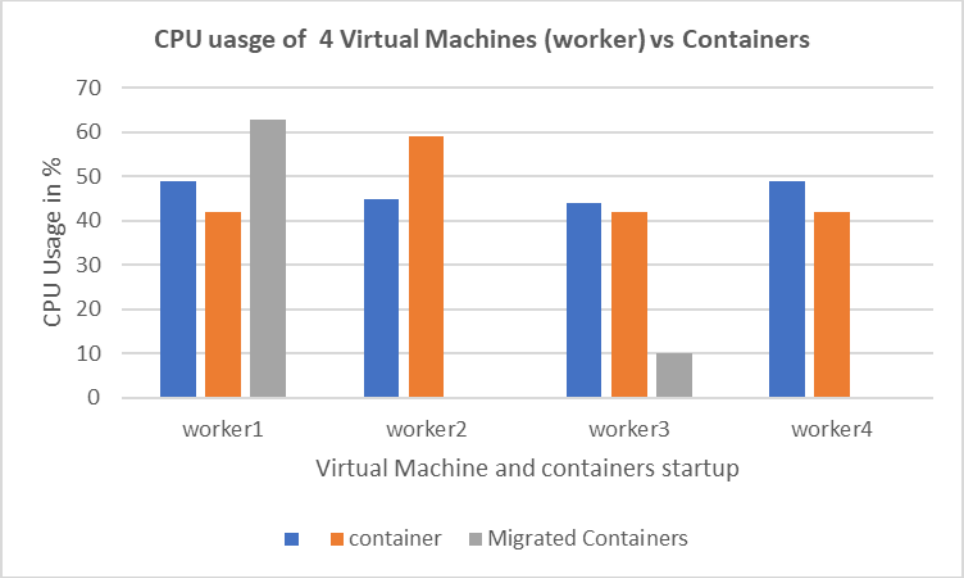


Figure 6: Shows CPU usage required to start containers and VMs

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From the above Fig (3) and (5), we can observe the CPU usage in percentage required to start VMs and Containers. Fig (3) shows 2 VMs and 2 containers, Fig (5) shows 4 VMs and 4 containers. In Fig (3) the container is assigned to worker 1 initially and one container is migrated from worker1 to worker2.When one container in migrated the CPU usage of worker1 is reduced. In Fig (5) worker1, worker2, worker3, worker4 are all assigned with one container each initially. Each worker shows equal startup CPU usage required for the start of containers. One container from worker3 is migrated to worker1 and hence the worker1 CPU usage also is increased. Fig (4) and Fig (6) shows startup time required by 2 VMs,2Containers and 4VMs, 4 Containers respectively. In 94% of CPU to start and worker2 requires 90% of CPU to start and run. Whereas the containers in worker1 take 45% and 60% of CPU to start up.IN worker2 containers take 40% of CPU to startup In Fig (6) shows the startup CPU percentage for VMs startup are 49%. 45%, 45%, 50% for worker1, worker2, worker3, worker4 respectively whereas the containers in each take 42%,60%,40%,40% of CPU time each. Worker1 is assigned 2nd container which is migrated from worker3 hence the CPU usage of worker1 is increased.

To conclude the start-up time for container has less CPU performance when compared to VM's. The containers itself holds all the dependencies required for the sucessful execution of the application and has taken less CPU time to startup and run whereas VMs have their own OS to startup so take more time comparatively. The experiments also analyzed the CPU time during container migration among VMs, it is observed from Fig (3) and Fig (6) that the CPU usage of the worker increases when the containers are assigned to them by other workers during migration

V. Conclusion

The study analysis the CPU performance during container migration among VM's and the start-up time required for VM and Container and the results of experiment shows that the start-up time for Container is less compared to VM's. The work analysis the container migration is performed in a single host real-time cloud server VM migration cannot to be performed, that can be considered as the future work.

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PROCEEDINGS OF 10[IH] INTERNATIONAL SYMPOSIUM ON FUSION OF SCIENCE AND TECHNOLOGY (ISFT-2024)
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EARLY RETINOPATHY PREDICTION MODELING BASED ON OPTIMAL MACHINE LEARNING ALGORITHMS PREDICTED FROM DIABETIC TYPE I AND TYPE II CLASSIFICATION

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ABSTRACT

Diabetes is difficult to forecast and is a globally alarming illness. Thus, the potential dangers are quite high. Slowly declining overall health might be another early indicator of diabetes. In the first phase of our study's diabetic prediction system, we use machine learning methods to determine the kind of diabetes a patient has. One significant method to streamline the diagnosis of diabetes is via the use of machine learning. Here, we use a machine learning technique on the PIMA health dataset. Type 2 diabetes may be predicted or classified using support vector machines, decision trees, LR, KNN, ANN, and logistic regression. The result demonstrates the best method's accuracy when compared to other classifications on the PIMAhealth dataset. Last but not least, we deal with diabetic retinopathy and use numerous categories to foresee potential eye damage. It's bad for your eyes and your eyesight, and it's bad for your internal organs, too. When the blood vessels just underneath the retina in our eyes swell and rupture, it disrupts brain function and leaves behind spots or pigments on the retina. Eventually, the guy will become blind because his blood vessels will rupture. One of the key treatments for this is detecting pigments and hotspots in the early stages of diabetes.

Keywords: Diabetes, healthcare, KNN, ANN, Machine Learning

[1] INTRODUCTION

Diabetes is a global, rapidly expanding, and highly unpredictable health crisis with several potential causes. According to The Hindu on November 14, 2019, the estimated population of India in 2021 is 1391.99 million, of whom 90 million would have diabetes. In addition, 134 million people will have diabetes by 2045, according to IDF and the ninth edition of the Atlas. Understanding type-1 and type-2 and discussing how to use Machine Learning methods to prevent issues in the future were primary goals of this study. Type 1, Type 2, and prediabetes may all be predicted using a model built from data gathered in hospitals and via online surveys. The ultimate

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purpose of the study is to enhance people's quality of life and reduce stress. Machine learning (algorithm) approaches are used to the processed data. Accuracy will be determined by applying several ML algorithms to separate datasets, with each dataset including its own unique collection of variables. Maximum precision in testing and education will aid in identifying the kind of diabetes. We describe the clinical information amassed from several surveys and hospital pathology labs, as well as the future risk factors associated with types 1 and 2. Forecasting a person's diabetes and providing relevant solutions to doctors using ML algorithms helps with the diagnosis of the condition and the provision of effective meds, clinical tests, and hospitality. Different types of insulin malfunction lead to different subtypes of diabetes.

- **Type I diabetes**: - This sort of internal cell generates insulin and is also known as "juvenile diabetes." Antibodies produced by the body itself (the autoimmune system) eliminate them. The absence of any insulin causes a condition that mostly strikes young individuals. The patient need immediate insulin treatment.

- **Type II diabetes**: - Type II diabetes is characterized by increased insulin resistance in the body. Type 2 diabetes is the leading cause of diabetes in adults. Difficulties arise from factors such as other P-Age and family history. Diabetic medications are given as needed. If the therapy and the patients themselves are ineffective, insulin is recommended for management of these disorders.

- **Gestational diabetes: -** This kind of diabetes often first appears during pregnancy. Similarities exist between this kind of diabetes and type 2. Women who are overweight are at a greater risk of developing gestational diabetes. Gestational diabetes may resolve after delivery, but it can also cause difficulties throughout pregnancy and affect the health of both the mother and the infant.

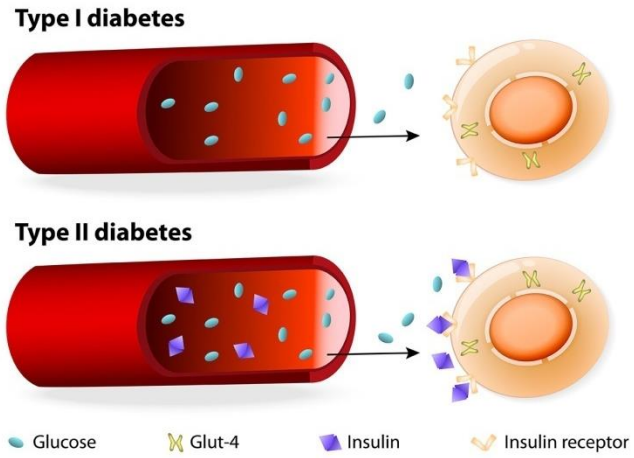


Fig:1 Types of diabetics

It's harmful to our organs over the long term, too. The kidneys, brain, heart, and eyes are

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particularly vulnerable.

- **Nervous system (neuropathy)**: Neuropathy refers to injury to the nerve system.The patient has lost the ability to feel pain and hence is unaware of even minor injuries, such as cuts, when they occur. When an infection spreads so far into these tissues, amputation may be the only choice left.

- **Eyes Retinopathy**: Retinopathy is the result of the breakdown of retinal blood vessels. For those with diabetes, this is a life-threatening problem. Patients were sometimes left permanently blind as a result of this. Here, it's important to check your eyes often.

- **Heart hypertension:** Hypertension may be diagnosed if blood pressure levels consistently rise over the normal range. The risk of complications from hypertension, such as heart disease and stroke, grows as blood pressure levels rise.

- **Brain**: Strokes and other forms of central nervous system infarction occur when the brain's many tiny blood arteries rupture, develop aneurysms, or form clots.

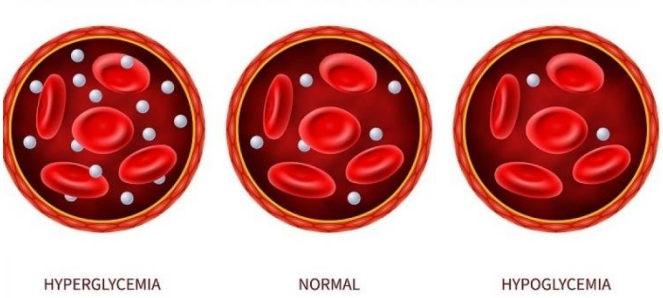


Fig: 2 level of blood sugar

Vision loss from diabetic retinopathy has decreased dramatically because to advances in diabetes and high blood pressure treatment, laser surgery, and ocular medicine administration. However, diabetes remains a major factor in visual impairment. The current research landscape on "Diabetic Retinopathy" is surveyed, and directions for further study are explored.

1.1 DIABETIC RETINOPATHY

The risk of developing either type 1 or type 2 diabetes exists in any population. Long-term diabetics with poorly managed blood sugar levels are at increased risk for developing this eye condition. Diabetic retinopathy is the main research topic at the moment. Diabetic eye defects are a collection of vision problems that arise exclusively from diabetes. If diabetic eye disease is not adequately detected and treated, it may lead to a variety of visual problems and possibly

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irreversible blindness. Diabetic retinopathy is the leading cause of blindness in people with diabetes and the most common type of diabetes-related eye illness. The blood vessels in the retina have changed, causing this condition.

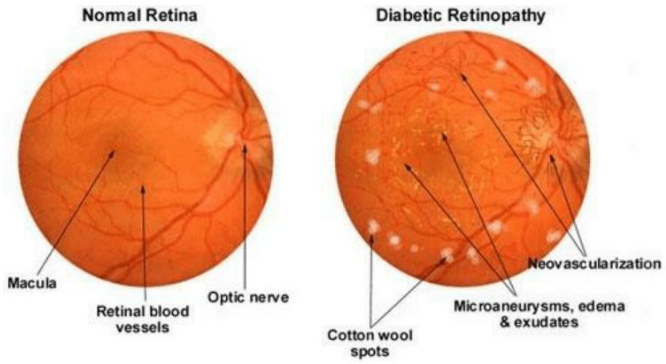


Fig: 3 Comparisons between Normal and Diabetic Retina

Diabetes mellitus, Type I, and Type II all increase the risk of developing eye disorders. The smaller the danger, the more effectively the patient can control their blood sugar. However, the danger increases as a diabetic patient ages. It may cause severe visual impairment or possibly blindness. Diabetic retinopathy is the most common complication of diabetes and a leading cause of blindness. Some people have trouble seeing in general, while others have floaters in their field of vision. Veins in the retina get damaged by diabetic retinopathy, and fluid and blood leak out. The macula, at the centre of the retina, is responsible for the finest vision. Focusing becomes more difficult over the course of months for those with diabetic retinopathy. This is called a "retinopathy issue" or "retinopathy difficulty," and it is typical and comparable to the symptoms of an impact and leaking in the retina before the development of knowledge and indications of diabetic retinopathy. Therefore, poor blood vessel health is associated with diabetes as a direct effect of high blood sugar. It begins with retinopathy, a condition characterised by a breakdown in the artery walls that leads to a variety of symptoms, including an increase in blood viscosity. The next stage, micro- vascular collusion, seems to be the worst since it disrupts blood flow and causes oxygen levels to drop dangerously low. There are two main types of retinopathy.

- Diabetic Retinopathy, Proliferative.
- Diabetic Non-Proliferative Retinopathy.

Retinopathy caused by diabetes that has progressed

New, aberrant blood vessels may form in the retina when a more severe form of diabetic retinopathy known as proliferative retinopathy causes the closure of injured blood vessels. The classification of healthcare data has the potential to significantly enhance its usefulness and

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efficiency. Several health-related categorization schemes are investigated in this research. In this research, we focus on proliferative diabetic retinopathy. For our purposes, it is necessary to collect data. This may be done by techniques like administering surveys or questionnaires through phone, mail, or the internet, or by mining information from preexisting databases like electronic medical records or other clinical data.

Data mining for classification work: Data mining begins with the classification of massive volumes of data in preparation for the subsequent discovery of patterns and relationships that will allow for data analysis and the resolution of problems. Classification is a technique for discovering a model that discovers various categories and types of data.

1.2 Classification

Identifying a method for classifying data that identifies and partitions data groupings or ideas and performs all required steps. The goal of classification is to use a model to predict a set of objects whose class label is unknown.The resultant model was developed by analysis of training data. That is to say, they are used to foretell missing or unknown numerical data values rather than class labels. A classifier is built using a library of known data classes or concepts. To create the classifier, the classification method examines and learns from a training set composed of database tuples and other data. There are just two stages to the data classification process. The first stage is to build a classifier or module that makes use of the selected set of data classes or ideas, which accounts for around 70% of the labelled data. We call this "training" or "learning" mode. Each row that is discussed or utilised by the classifier's learning module will have a reference to it in the class label property, which will be a reference to a distinct class labelled database. The value of the attribute is not ranked and it belongs to a certain class. Class labels for each tuple are either known or supplied, making this an example of supervised learning.

1.3 Deep learning

Artificial intelligence (AI) deep learning is a technique that simulates the way the human brain processes information. Images, texts, sounds, and other data may all be processed by deep learning models to provide insightful conclusions and reliable forecasts. In order to automate activities that would otherwise need human intellect, such as describing photos or transcribing audio into text, deep learning techniques may be used.

1.4 ML (MACHINE LEARNING)

Machine learning (ML) is a subfield of AI that helps programmers improve their predictive abilities over time even if they weren't taught to. Predictions from machine learning algorithms are based on past data. One popular use of machine learning is in recommendation engines. Business

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process automation (BPA), Predictive maintenance, and the detection of fraud and spam are among common applications.

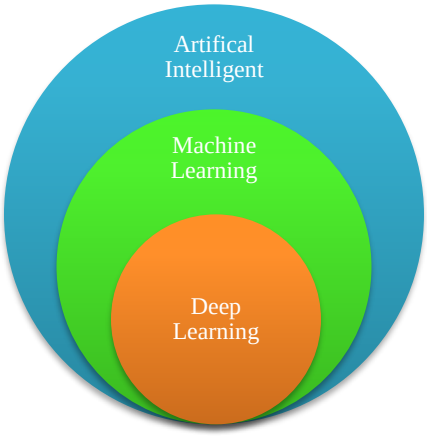


Fig: 4 Machine Learning

1.5 The Benefits of Deep Learning Over Machine Learning

The following are some of the advantages of a deep learning network over more conventional machine learning methods.

- **Efficient processing of unstructured data**

Unstructured data, such as text documents, are difficult to analyse using machine learning algorithms since the training dataset might contain unlimited variations. Deep learning algorithms, on the other hand, don't need human feature extraction to make sense of unstructured data and draw broad conclusions. For instance, a neural network can tell that the following two input phrases are equivalent to one another:

- May you please explain how I may send in my payment?
- Where can I send money?

- **Hidden relationships and pattern discovery**

Deep learning software can do more in-depth analyses of massive data sets and uncover previously hidden insights. Take, as an example, a deep learning model that has been taught to analyse retail sales. Only products you have previously bought are included in the model's data. The artificial neural network, however, may recommend products you haven't tried before by comparing your purchasing habits to those of other consumers with similar profiles to yours.

- **Unsupervised learning**

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Models trained using deep learning may adapt to new situations and become better over time. They can function with smaller samples of labelled data. Think of a neural network that learns from your typing habits and then makes suggestions and corrections as you type. In this scenario, we will presume it has been taught English and can correct misspelt English words. However, the neural network learns and autocorrects non-English terms, such as danke, if you input them regularly.

- **Volatile data processing**

Large fluctuations characterize volatile datasets. Bank loan payback amounts are one such example. This data may also be sorted and classified by a deep learning neural network, for example, by analysing bank transactions and marking some of them for fraud detection.

1.5 MACHINE LEARNING TYPES

The algorithm learns from a collection of instances where the correct responses are provided (targets) and then generalises to successfully reply to all inputs. Learning through observation is another name for it.

- **Unsupervised learning:** In this approach, the solutions are not provided; rather, the algorithm searches for patterns in the inputs to classify them into groups with similar patterns. Unsupervised learning often employs the statistical technique of density estimation.

- **Reinforced learning:** Learning that combines aspects of both supervised and unsupervised approaches. The algorithm is alerted when a wrong response has been provided, but it is not given correction instructions. It has to do some digging and try out several different strategies before it can figure out how to provide the right answer. Reinforcement learning is sometimes known as learning with a critic due to the fact that a monitor evaluates each answer and provides a score without offering any constructive feedback.

- **Evolutionary learning:** To improve their chances of survival and reproducing, organisms learn to adapt to their circumstances, which is one definition of biological progress. They take a look at how this might be modelled computationally by using fitness, which can be thought of as a score for how efficient the present strategy is. The next several chapters will focus on supervised learning, which accounts for the vast bulk of learning. Therefore, we will first define it and discuss the types of problems that may be addressed with it.

ML based diabetic prediction techniques - In diabetic research, we tallied how often we used various machine learning classifiers. The most popular classifiers for diabetes prediction were ANN, neural networks, SVM, DT, and NBM.

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- **Artificial Neural Network-** ANN simulate the functioning of the human nervous system. Through trial and error, they may be able to separate superfluous information from crucial details and learn how to handle ambiguous circumstances with ease. The three main components of an ANN are the input, output, and hidden layers. Neurons that execute data operations to facilitate better learning are hidden in the hidden layer. There are striking parallels between an artificial neural network and the brain's own neural network. The signal route in ANNs is often a multi-layered or cube-shaped structure that moves from the front to the rear. When the desired result is already known, back propagation may be used in conjunction with upward stimulation to reset weights on the "front" neural units. Connections in modern networks are less tightly controlled, allowing for more stimulation and inhibition. Dynamic neural networks, which can add or remove brain units and connections on the fly according to predetermined criteria, are currently the most advanced kind of neural network. Layers and a network function are the basic building blocks of any artificial neural network. There are three distinct layers in a neural network: input, hidden, and output.

- **Support vector machine,** we may classify the data points with high precision while using minimal computational resources in N-dimensional space. When separating the data set from the strategy, hyper planes are the decision boundaries utilised to do so. Strong SVM can determine the margin between the plane and the data sets with the aid of the cost function and the gradient. Algorithms are taught to make predictions after being given training data sets. The method provides a step-by-step solution, including testing, consultation with a doctor, and prescription of medication, if a diagnosis of diabetes has been anticipated and confirmed based on clinical data. For the backend, we use Python, and for data analytics in Python Panda, we make use of several libraries (such as matplotlib and pyplot) and CSS for the user interface.

- **Decision tree classification-** The decision-making process is the foundation of a decision tree. It's like a tree in that it offers incredible accuracy and longevity.

- **K-Nearest Neighbor Classifier-** Despite its popularity for dealing with classification problems, the K-Nearest Neighbour (KNN) method is equally at home when used to regression issues. Its primary advantages are its readability and computational speed. The coordinates and in Following figure may be placed in any of the clusters. When determining how far apart two sets of data are, the KNN employs the Euclidean distance function.

[2] LITERATURE REVIEW

A. Berina et al. (2017) reviewed the classification of diabetes and cardiovascular disease using machine learning methods.Multilayer feedforward neural networks trained using the Levenberg-Marquardt technique predominated in the publications they looked at. However, Na'ive Bayesian networks are the most used form of BN, and they had the greatest retrospective accuracy rates (99.51% and 97.92%) for classifying diabetes and CVD,

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respectively. Additionally, ANN has demonstrated superior results when calculated the mean accuracy of observed networks, suggesting a greater likelihood of obtained correct findings when applied to diabetes and/or CVD classification. [1]

N. S. Khan et al. (2017) focused on the machine-learning-based mobile health app for diabetes prediction.millions of individuals all around the world suffer with diabetes mellitus, a chronic and lifestyle illness. world succumb to its effects. While there were applications available for monitoring your diet, blood sugar, medication, and daily activities, measurements of blood sugar, blood pressure, and weight, as well as the distribution of recommendations for diet and exercise in the management of diabetes. There was no known software that was designed specifically to assess the likelihood of complications if you have diabetes. This research aims to do just that by creating a smart mHealth app.Using AI to predict how likely they are to be successful. whether they are type 1 or type 2 diabetes, prediabetic, or a healthy medical practitioner, or diagnostic procedures. [2]

R. Pal et al. (2017) introduced the diabetic retinopathy as a candidate for use of machine learning algorithms. Clinical data analyzed makes use of machine learning, a subfield of AI, because of its ability to recognise patterns in data and extrapolate those patterns to make inferences or predictions in the face of ambiguity. When dealing with DR, it was crucial to determine whether or if there is a connection between the therapist's level of attachment for the patient and the patient's therapeutic outcome. In this research, they evaluate and validate the results of many machine learning techniques for a specific DR data set.[3]

I. Kavakiotis et al. (2017) did research on diabetes using machine learning and data mining techniques. The current research aims to conduct a systematic review of the uses of machine learning, data mining techniques, and tools in diabetes research, specifically in the areas of a) Prediction and Diagnosis, b) Diabetic Complications, c) Genetic Background and Environment, and e) Health Care and Management. Machine learning algorithms from a broad variety of families were used. In general, supervised learning techniques accounted for 85% of the methods used, while unsupervised methods, and association rules in particular, accounted for the remaining 15%. The most popular and productive approach was SVM. In terms of data types, clinical datasets were the most common. The publications were chosen because their titles foreshadow the potential for extracting beneficial information that might lead to new hypotheses aimed at a more thorough comprehension of DM. [4]

M. A. Sarwar et al. (2018) presented work on the medical diabetes prediction using deep neural networks. In this study, they explore the application of six distinct machine learning

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algorithms to the field of healthcare predictive analytics. Six different machine learning algorithms are applied to a dataset consisting of medical records from a sample of patients for the aim of this experiment. They examine and contrast the performance and precision of the various algorithms used in this study. This research uses a variety of machine learning methods to determine which algorithm was most effective for diabetes prediction. The purpose of this study was to provide medical professionals with a tool for early diabetes prediction using machine learning methods.[5]

Predicting Severe Retinopathy of Prematurity with an Interpretable Machine Learning Approach Using a Generalised Additive Model with Pairwise Interactions (GA2M). Using statistical analysis and logistic regression as a kind of generalised additive model (GAM) with pairwise interaction terms (GA2M), they had looked at the variables that cause serious retinopathy of prematurity. When applying machine learning to clinical data, they address the tradeoff between precision and human understanding. They also validate the experience-based judgement of neonatologists about the clinical significance of certain risk variables, such as gender, for RoP prediction.[6]

R. Aminah et al. (2019) introduced the machine-learning-supported iridological diabetes prediction system. This technique may indicate the health of the organ before any indications of illness occur. In this study, they used machine learning to develop an iridology- or iris-image-based diabetes prediction system. Detection was made easier with the use of machine learning. The system's components include hardware and software for capturing and processing images of the eye. The irises were photographed using an iridology camera and analyzer. In order to extract texture features from a picture, the GLCM technique was often used. Diabetic and non-diabetic groups were separated using the kNN approach. The k-fold cross-validation technique was then used to check and assess the categorization findings using the confusion matrix. There were 16 non-diabetic patients and 11 diabetes subjects in the study. Based on the data, they know that the accuracy is 85.6 percent, the FPR is 11.7 percent, the FNR is 20.4 percent, the specificity is 0.889, and the sensitivity is 0.796.[7]

L. Alic et al. (2018) did research on diabetes risk assessment in a healthy population. They use support vector machines with 10 variables that have been shown to be robust predictors of future diabetes in the published literature. The dataset is imbalanced in terms of the class labels, therefore first train the model using 10-fold cross-validation and validate it using a hold-out set. The average validation accuracy across 100 iterations in this investigation was

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84.1%, with an average recall rate of 81.1%. The results of this research may be used to better understand who is at risk for getting type 2 diabetes in the future.[8]

A. Mujumdaz et al. (2019) looked machine learning algorithms for diabetic risk assessment. Many individuals struggle with diabetes mellitus, making it a serious health issue. Diabetes Mellitus may be brought on by a wide variety of factors, including advanced age, began overweight, not get enough exercise, having a family history of the disease, leading an inactive lifestyle, eating poorly, had high blood pressure, etc. Diabetics were at increased risk for a wide variety of health issues, included cardiovascular disease, renal failure, stroke, vision loss, nerve damage, and more. As it stands, hospitals routinely perform a battery of tests in order to get the data needed to diagnose diabetes. Treatment was given according to the diagnosis. In healthcare, big data analytics plays a crucial role. Industries. Large-volume databases were commonplace in the healthcare industry. Big data analytics allows users to examine massive data collections and uncover concealed meaning and root causes in data for the purpose of making informed predictions. Accordingly. Classification and prediction accuracy were low using current methods. This article presents a to improve diabetes categorization, a prediction model was devised that relies on just a small number of outside variables.Accountable for diabetes along with the usual suspects like glucose, body mass index, age, insulin, and so on. Precision in classifying data was improved with the addition of the new data set over the old one.[9]

N. P. Tigga et al. (2020) introduced the machine learning for predicting type 2 diabetes. Machine learning algorithms were used to predict Type 2 diabetes risk because of their superior accuracy, which is essential in the medical field. Individuals would be able to accurately identify their own risk of developed diabetes after the model has been trained. To conduct the study, 952 participants had been surveyed by online and paper-and-pencil questionnaires on their health, lifestyle, and family history. This was also done using the Pima Indian Diabetes database using the same techniques. For both data sets, Random Forest Classifier proves to be the most effective classification method. [10]

B. Farran et al. (2019) reviewed the future risk of type 2 diabetes using non-invasive parameters and machine learning algorithms in kuwaiti health data. There had been a rise in the incidence of T2DM in recent decades among the Arab population, especially in the countries of the Gulf Cooperation Council. In this regard, the capacity to identify persons at risk of developing T2DM was crucial for early intervention efforts. They compared machine-learning techniques with traditional logistic regression (LR) and with simple non-invasive

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clinical indicators across three time horizons to develop predictive models for the risk of T2DM in the Arab population. Machine learning methods are a great complement to the well-known LR strategy. Early preventive strategies for high-risk groups in the Arab community might be aided by the results of their T2DM prognostic models.[11]

P. Sonar et al. (2019) considered the diabetes with various machine learning methods. They had a cut-edge method that uses data science to determine whether a person was likely to develop type 2 diabetes. In addition, began able to foresee the onset of the illness was crucial in prepared the patients for its onset. With information withdrawal, hidden details about diabetes may be scrubbed from a database. The research aim to create a method that might more accurately identify a patient's risk for developing diabetes. Models are built using classification techniques included Decision Trees, Artificial Neural Networks, Naive Bayes, and Support Vector Machines. Accuracy estimates range from 85% for Decision Tree to 77% for Naive Bayes to 77.3% for Support Vector Machine. The results demonstrate the high precision of the approaches used.[12]

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Table1: Literature Review

Sno.	Author/Year	Title	Methodology	Limitation
[1]	B. Alić , et al. / 2017	Machine learning techniques for classification of diabetes and cardiovascular diseases	ML, Diabetes, Cardiovascular diseases	Scope of work is limited
[2]	N. S. Khan, et al. / 2017	Diabetes Predicting mHealth Application Using Machine Learning	Machine Learning, Diabetes	Research is limited to traffic flow
[3]	R. Pal, et al. / 2017	Application of machine learning algorithms on diabetic retinopathy	ML	There is not performed in future
[4]	I. Kavakiotis, et al. / 2017	Machine Learning and Data Mining Methods in Diabetes Research	ML, Diabetes	Lack of efficiency
[5]	M. A. Sarwar, et al. / 2018	Prediction of diabetes using machine learning algorithms in healthcare	Machine learning, Diabetes	Need to improve the performance and accuracy
[6]	T. Karatekin , et al. / 2019	Interpretable Machine Learning in Healthcare through Generalized Additive Model with Pairwise Interactions (GA2M): Predicting Severe Retinopathy of Prematurity	Machine Learning	There is lack of performance
[7]	R. Aminah , et al. / 2019	Diabetes prediction system based on iridology using machine learning	Diabetes , ML	Research is limited to traffic flow
[8]	H. Abbas et al. /2019	"Predicting diabetes in healthy population through machine learning	ML , Diabetes	There is less technical work
[9]	A. Mujumdar, et al. / 2019	Diabetes Prediction using Machine Learning Algorithms	ML , Diabetes	Lack of security and accuracy
[10]	N. P. Tigga , et al. / 2020	Prediction of Type 2 Diabetes using Machine Learning Classification Methods	Diabetes , ML	There is lack of performance

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[11]	B. Farran, et al. / 2019	Use of Non-invasive Parameters and Machine-Learning Algorithms for Predicting Future Risk of Type 2 Diabetes: A Retrospective Cohort Study of Health Data From Kuwait	ML, Diabetes	Lack of technical work
[12]	P. Sonar, et al. /2019	Diabetes prediction using different machine learning approaches	Diabetes , ML	Performance of this research is very low

[3] Problem Statement

Despite the fact that its 1,393 million citizens have such hectic lives that they have little time to devote to their health, a recent poll suggests that India may surpass China as the world's most populated country by the middle of this decade. The International Diabetes Federation (IDF) in the United States estimates that by 2040, there will be 134 million individuals with diabetes in India, making it the country with the second-highest diabetic population. The population, economics, and demographics of a nation all play a role in why so many people don't take care of their health until something catastrophic happens to them. It's possible that the development of families, communities, and nations might be impacted directly or indirectly by the unexpected harm that diabetes causes. Since this is also a major issue for the younger generation, it must be detected early on, treated effectively, and managed in a user-friendly manner with the help of intelligent systems (ML). Taking diabetes as an example, it is clear that this is a critical issue for humans, and that the only way to deal with it is by early detection and careful attention to one's diet.

[4] Need of research

Diabetes is a worldwide health crisis that is difficult to predict. As a result, the risks are substantial. Deterioration in general health may also be an early warning sign of diabetes. We employ machine learning techniques to classify the kind of diabetes a patient has in the first stage of our diabetic prediction system. Using machine learning to expedite diabetes diagnoses is an important step in this direction. The PIMA health dataset is used in conjunction with a machine learning approach here. Support vector machines, decision trees, LR, KNN, ANN, and logistic regression may all be used to make predictions or categorise people with type 2 diabetes.

[5] Scope of research

When compared to various classifications on the PIMAhealth dataset, the outcome shows that the best technique is the most accurate. Finally, we discuss diabetic retinopathy and the several

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classifications we use to forecast the onset of eye impairment. It's not good for your internal organs, your eyes, or your vision. The brain's ability to function is disrupted and spots or pigments are left on the retina when blood vessels right below the retina in our eyes enlarge and burst. The ruptured blood vessels will cause the man's blindness in due time. Early detection of diabetes by looking for pigments and hotspots is an important part of therapy.

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Data Analytics for Multi-criteria ABC Analysis and Supplier Segmentation in Making a Competitive Supply Chain Using Python

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Abstract

A typical supply chain is designed to meet the ultimate customers' requirements by managing the flow of materials, information and finances from suppliers to the customers. Multi-criteria ABC analysis plays an important role in understanding various types of products viz. volume drivers, margin drivers, regular and slow movers. The paper aims at performing multi-criteria ABC analysis on the online retail dataset using Data Analytics techniques. Further, the performance of four Machine Learning classification algorithms is also compared for multi-criteria ABC analysis. Also, the importance of supplier segmentation for making a competitive supply chain is being discussed.

Keywords: Supplier Segmentation, Multi-criteria ABC Analysis, Supply Chain Management, Data Analytics, Classification Algorithms

Introduction

In today's world, customers have more choices and they demand more value for money. The companies are trying to cope with the changing market conditions. Availability of quality products/services at reasonable prices is the demand of the hour. The global competition has forced companies to increase their focus on customers' expectations. The evolution of internet technology has made it possible to trade online and e-commerce has become a great success nowadays. In quest of serving the customers' demand, companies are producing a wide range of products and at the same time trying to reduce costs. Therefore, an integrated approach was needed to address these challenges and the concept of Supply Chain(SC) consisting of suppliers, manufacturers, warehouses, retailers and customers has come into existence. A typical supply chain is designed to meet the ultimate customers' requirements by managing the flow of materials, information and finances from suppliers to the customers. Supply Chain Management (SCM) looks after all these activities to meet the customers' demands and simultaneously tries to satisfy the desired service level at a minimized cost. Over the years, data has increased exponentially. Data Analytics has enabled the designers of SC to visualize, predict and prescribe the approaches to optimize the performance of SC. Classification of products and supplier segmentation play an important role in making strategies for competitive advantage. For the classification of inventory items, ABC analysis has been used across the industry. But, this approach has its limitations [1]. In this paper,

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an effort is being made to analyze the online retail dataset [2] for simple and multi-criteria ABC analysis. First of all data has been cleaned by removing null values and duplicate entries. Then, using Python's 'inventorize' package ABC and multi-criteria ABC analysis was performed. After this analysis, the performance of classification algorithms viz. Naïve Bayes, K-Nearest Neighbour, Logistic regression and Decision Tree Classification have been compared for the given data set. Also, the importance of supplier segmentation in optimizing the performance of the entire supply chain has been discussed.

ABC Analysis

In general, equal control efforts for all the products in inventory are not recommended. The higher-valued items might become critical to the existence of the business. The ABC analysis based on Pareto Principle classifies the items into three categories viz. A 'accounting for a large fraction of the total inventory value', B 'moderate value' and C 'accounting for least fraction of the total inventory value' [3]. Class A items are associated with high stock-out costs and close control is required for these items. Stock-out costs for Class B items are at a moderate level, while Class C items constitute a major portion of the inventory items and are associated with low stock-out costs.

Multi-criteria ABC Analysis

ABC analysis has a lot of benefits for inventory management. However, the usefulness of ABC analysis is affected by the different specifications like customer demand patterns, classification systems and other parameters of business units [4]. The ABC classification was done on the basis of annual dollars initially [5]. Later on, multiple criteria like lead time, profit, criticality, demand distribution etc. were taken into consideration for the classification of items [6]. The classification considering multiple criteria is necessary to cater for the needs of the management in the current scenario.

ABC Analysis using Inventorize Package

Python package 'inventorize' is useful for simulating inventory policies, and calculating inventory analytics such as stock levels, reorder points etc. It includes ABC analysis calculation, inventory metrics, multi-product optimization and logit model optimization [7]. The 'ABC' method of inventorize package is being used for performing the ABC analysis, while its 'productmix' method is utilized for performing multi-criteria ABC analysis.

Supplier Segmentation

As we know, companies have a large number of suppliers to meet the objective of differentiation strategy for gaining competitive advantage. For such companies, supplier segmentation becomes one of the key activities of supplier relationship management (SRM). In general, it is dividing the

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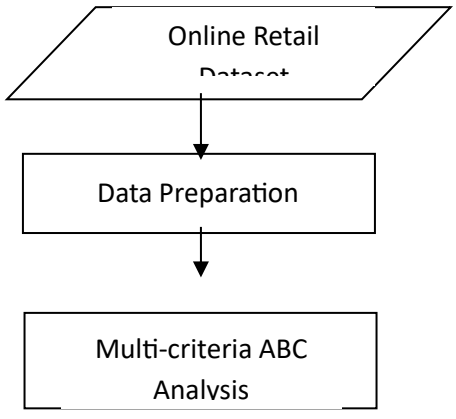
suppliers into segments and then formulating strategies for the segment [11].

Literature Review

Qaffas et al. (2023) carried out interpretable multi-criteria ABC analysis based on Semi-Supervised Clustering and explainable Artificial Intelligence(AI). They used semi-supervised techniques to classify items satisfying Pareto law. Further, detailed explanations at the class and item level were prepared using AI [1]. Yemane et al. (2021) compared traditional ABC analysis with a new optimal multi-criteria ABC analysis. They considered unit price, lead time and annual usage for the classification [8]. Min-Chun Yu (2011) performed multi-criteria ABC classification using Artificial –intelligence-based classification techniques [9]. Chen et al.(2008) introduced a case-based multiple-criteria ABC analysis, which included lead-time, and criticality of SKUs as additional criteria along with annual dollar usage [10]. Nellore et al. (2000) examined existing approaches to supplier segmentation in automotive companies and established a relationship between product categories and supplier characteristics [12]. Svensson (2004) performed supplier segmentation in the automotive industry and introduced four supplier relationship strategies [13]. Further, he proposed a process for managing supplier relationships consisting of four steps: business environment analysis, relationship criteria analysis, relationship strategy selection and managerial decisions. Day et al. (2010) reviewed the articles available at that time in terms of market conditions, supplier characteristics, buyer characteristics, and buyer and supplier relationships [14]. Rezaei et al. (2013) developed a new approach for supplier segmentation. They applied fuzzy logic for supplier segmentation of a broiler company [15].

Present Work

In this paper, an effort is being made to analyze the performance of classification algorithms viz. Naïve Bayes, K-Nearest Neighbour, Logistic regression and Decision Tree Classification for multi-criteria ABC analysis using Python. The flow of the present work has been shown in Fig 1.



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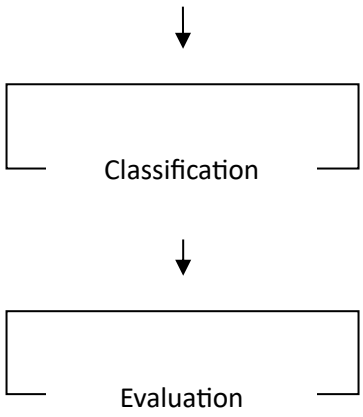


Fig.1 Workflow

First of all online retail dataset [2] was read in a dataframe named data. It contains eight columns viz. InvoiceNo, StockCode, Description, Quantity, InvoiceDate, UnitPrice, CustomerID and Country. The sample dataset is shown in Fig. 2.

```
In [3]: data=pd.read_excel('Online Retail.xlsx')

In [4]: data.head()

Out[4]:
```

	InvoiceNo	StockCode	Description	Quantity	InvoiceDate	UnitPrice	CustomerID	Country
0	536365	85123A	WHITE HANGING HEART T-LIGHT HOLDER	6	2010-12-01 08:26:00	2.55	17850.0	United Kingdom
1	536365	71053	WHITE METAL LANTERN	6	2010-12-01 08:26:00	3.39	17850.0	United Kingdom
2	536365	84406B	CREAM CUPID HEARTS COAT HANGER	8	2010-12-01 08:26:00	2.75	17850.0	United Kingdom
3	536365	84029G	KNITTED UNION FLAG HOT WATER BOTTLE	6	2010-12-01 08:26:00	3.39	17850.0	United Kingdom
4	536365	84029E	RED WOOLLY HOTTIE WHITE HEART.	6	2010-12-01 08:26:00	3.39	17850.0	United Kingdom

Fig.2 Sample Dataset

The dataset contains 541909 rows and 8 columns. After dropping the rows containing null values and duplicate entries, the dataset contains 401604 rows. Finally, those rows in which the quantity is more than zero are kept in the dataset. For multi-criteria ABC analysis, one column "Revenue" was added to the dataset. Revenue is calculated by multiplying quantity with unit price in the given dataset. After that only relevant columns viz. ‘StockCode', 'Description', 'Quantity' and 'Revenue' were kept for the analysis. The

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data was prepared for performing ABC analysis and multi-criteria ABC analysis. Python's 'inventorize' package is used to perform the ABC analysis based on volume and revenue.

Next, multi-criteria ABC analysis was performed based on Quantity and Revenue to obtain the classification of items as A_A, A_B, A_C, B_A, B_B, B_C, C_A, C_B, and C_C as shown in Fig 3. Categories A_B and A_C represent volume driver items, B_A and C_A represent margin driver items, categories B_B, B_C and C_B represent regular items, and C_C category represents slow-moving items while A_A represents margin and volume driver items.

```
In [33]: #Multicriteria ABC Analysis
         data_multiabc=inv.productmix(data_abc['Description'],data_abc['Quantity'], data_abc['Revenue'])

In [34]: data_multiabc.columns

Out[34]: Index(['skus', 'sales', 'revenue', 'sales_mix', 'comulative_sales',
                'revenue_mix', 'comulative_revenue', 'sales_category',
                'revenue_category', 'product_mix'],
               dtype='object')

In [35]: data_multiabc.product_mix.value_counts()

Out[35]: C_C    1802
         A_A     560
         B_B     397
         C_B     288
         B_C     282
         A_B     275
         B_A     196
         C_A      53
         A_C      44
         Name: product_mix, dtype: int64
```

Fig. 3 Multi-criteria ABC analysis based on Qunatity and Revenue

The dataset obtained after performing multi-criteria ABC analysis was used for the comparison of four classification algorithms viz. Naïve Bayes, K-Nearest Neighbour, Logistic Regression and Decision Tree Classification. For comparing the classification algorithms, the accuracy score of each model was considered and a confusion matrix was created for each model to measure the classification performed by the said algorithms.

Results and Discussion

After the execution of codes, the following results have been obtained for the KNN classification algorithm as shown in Fig. 4.

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```
In [51]: from sklearn.metrics import confusion_matrix
         cm = confusion_matrix(ytest,ypred,labels=model.classes_)
         cm

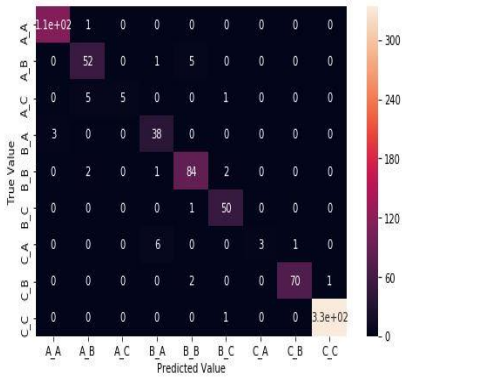
Out[51]: array([[111,   1,   0,   0,   0,   0,   0,   0,   0],
                [  0,  52,   0,   1,   5,   0,   0,   0,   0],
                [  0,   5,   5,   0,   0,   1,   0,   0,   0],
                [  3,   0,   0,  38,   0,   0,   0,   0,   0],
                [  0,   2,   0,   1,  84,   2,   0,   0,   0],
                [  0,   0,   0,   0,   1,  50,   0,   0,   0],
                [  0,   0,   0,   6,   0,   0,   3,   1,   0],
                [  0,   0,   0,   0,   2,   0,   0,  70,   1],
                [  0,   0,   0,   0,   0,   1,   0,   0, 334]], dtype=int64)

In [52]: from sklearn.metrics import accuracy_score
         a = accuracy_score(ytest,ypred)
         a

Out[52]: 0.9576923076923077
```

(a)

```
In [102]: plt.figure(figsize=(8,5))
          draw_confm(df['Actual'],df['Predicted'])
```



(b)

Fig. 4 (a) Accuracy score for KNN classifier (b) Graphical representation of confusion matrix

The Decision Tree classification algorithm performed multi-criteria ABC analysis with an accuracy score of 0.9987179487179487, while that of Logistic regression was 0.7794871794871795 as shown in Fig. 5.

```
In [67]: accuracy_score(y_test,pred_tree)

Out[67]: 0.9987179487179487

In [68]: confusion_matrix(y_test,pred_tree)

Out[68]: array([[116,   1,   0,   0,   0,   0,   0,   0,   0],
                [  0,  54,   0,   0,   0,   0,   0,   0,   0],
                [  0,   0,   7,   0,   0,   0,   0,   0,   0],
                [  0,   0,   0,  39,   0,   0,   0,   0,   0],
                [  0,   0,   0,   0,  83,   0,   0,   0,   0],
                [  0,   0,   0,   0,   0,  60,   0,   0,   0],
                [  0,   0,   0,   0,   0,   0,  11,   0,   0],
                [  0,   0,   0,   0,   0,   0,   0,  59,   0],
                [  0,   0,   0,   0,   0,   0,   0,   0, 350]], dtype=int64)
```

(a)

```
In [77]: accuracy_score(y_test,pred)

Out[77]: 0.7794871794871795

In [78]: confusion_matrix(y_test,pred)

Out[78]: array([[116,   0,   0,   0,   1,   0,   0,   0,   0],
                [  9,  33,   1,   0,  11,   0,   0,   0,   0],
                [  0,   6,   1,   0,   0,   0,   0,   0,   0],
                [ 19,   0,   0,  10,  10,   0,   0,   0,   0],
                [  0,   2,   0,   0,  79,   0,   0,   0,   2],
                [  0,  13,   0,   0,  13,   4,   0,   0,  30],
                [  2,   0,   0,   6,   0,   0,   0,   3,   0],
                [  0,   0,   0,   0,  19,   0,   0,  15,  25],
                [  0,   0,   0,   0,   0,   0,   0,   0, 350]], dtype=int64)
```

(b)

Fig. 5 Accuracy score for (a) Decision Tree classifier and (b) Logistic Regression

The Naïve Bayes classifier performed the analysis with an accuracy score of 0.9141025641025641. The confusion matrix for the same has been shown in the Fig. 6.

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```
In [96]: plt.figure(figsize=(5,5))
         draw_confm(df3['Actual'],df3['Predicted'])
```

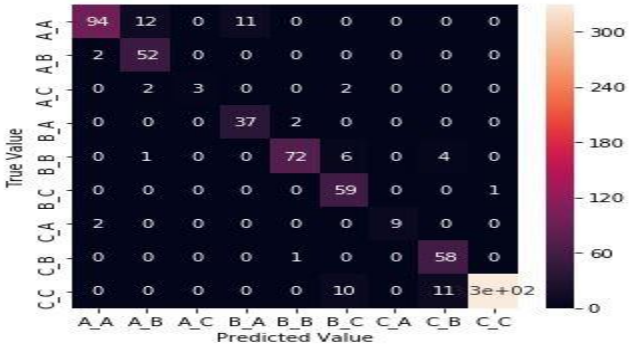


Fig. 6 Confusion Matrix for Naïve Bayes classifier

The graph for the accuracy score of all classification algorithms is shown in Fig. 7.

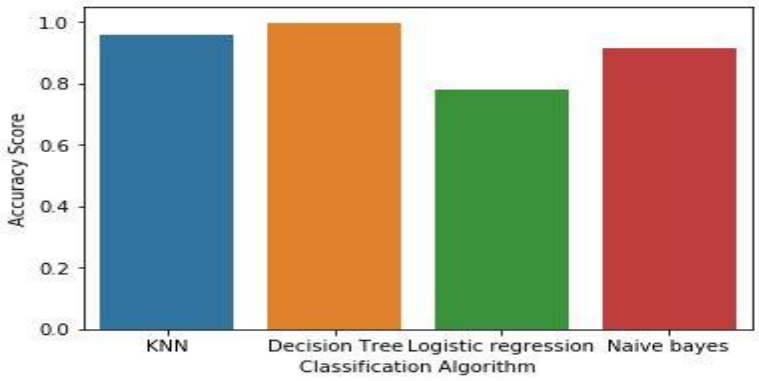


Fig. 7 Comparative accuracy score for different classifiers

Conclusions

In general, it can be said that SCM is nothing but the management of products/services from the upstream to the downstream when it is ready to be used by the customers. The improvement in the performance of the supply chain depends upon the overall improvement in the activities across the supply chain. As customers are demanding a variety of products and at the same time want more value for the money; it is important to understand the various types of products viz. volume drivers,

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margin drivers, regular and slow movers. Analytics in the SCM plays a crucial role in making the supply chain a robust one and adapting according to the needs of the customers. Identification of suppliers for strategic partnership is an important step for long-term performance improvement of the entire supply chain; while at the same time identifying bottlenecks for the supply chain allows for preparing for the risks involved in future. Multi-criteria ABC analysis is a useful mechanism to perform this segmentation. In this paper, an effort is being made to compare the performance of classification algorithms for performing multi-criteria ABC analysis on online retail dataset. In today's online business world, classifying the items and identifying the suppliers supplying critical items become essential for the survival of business. On this basis, strategic alliances can be made for volume and margin driver items. The 'inventorize' package is a useful tool of Python for performing multi-criteria analysis based on quantity and revenue. It could be useful in identifying the important items to store. Further, knowing the fast-moving items can provide great help in warehouse management. From the results obtained it can be concluded that among the classification algorithms compared based on accuracy score, Decision Tree Classifier performed the best. It can be used for performing the multi-criteria ABC analysis. In future, other fields can also be included in this analysis.

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A Comprehensive Study of Network Intrusion Detection System Models Using Deep Learning

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Abstract: Nowadays, speedy advances in the communication and internet field have revealed large developments in network data and analogous network size. Consequently, various novel attacks, viruses, and vulnerabilities to hackers are being generated which seriously threaten the property and privacy security of users as well as pose novel challenges to efficiently detect them in the network security domain. Network Intrusion Detection System (NIDS) represents a tool used to prevent network by inspection of network traffic from novel intrusions to ensure network CIA aspects (confidentiality, integrity, and availability). Additionally, the severity and complication of network security attacks have encouraged researchers to incorporate various machine learning approaches to prevent organizations' reputations and data. Regardless of the vast efforts done by the researchers, NIDS still appears to have difficulties in enhancing intrusion detection accuracy while minimizing false alarm rates. Deep learning (DL) can act as one of the promising approaches that have largely been employed in the network security domain to enhance intrusion detection performance while securing networks and hosts in comparison to ML approaches effectively. This survey paper provides insights into NIDS concepts and taxonomy based on DL methodologies in designing secure NIDS. In this survey paper, a systematic literature review of various recent articles is taken by discussing the pros and cons of proposed methodologies. Then, recent advancements and trends of DL-based approaches in terms of methodology, dataset selection, and their proposed methodology are defined for securing network aspects. Lastly, this survey paper focused on potential research challenges by considering the shortcomings of proposed methodologies for enhancing intrusion detection accuracy in networks.

Keywords: Cybersecurity, DL, NIDS, Network Security, AE, CNN.

1. Introduction

Recent development in the improvement of the web and networks, correspondence advances in comparison to the previous decade, security of network has arisen as an imperative exploration space. It takes advantage of its instruments namely antivirus programming, firewall, and intrusion detection framework (IDS) to provide organization security assurance as well as its related resources inside a cyber environment [1]. Amid these, network-based interruption location framework (NIDS) is the assault identification instrument that gives the required security by regularly monitoring organization traffic for pernicious and abnormal behavior [6,7].

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Security of these information and organization hubs has turned into a provoking errand because of the age of countless new goes after by the same token through the transformation of an old assault or a clever assault. Pretty much every hub inside an organization is helpless against security dangers. For example, the information hub might be vital for an association. Any split of the difference in the hub's information might cause a tremendous effect based on its market conditions and monetary misfortunes. Current IDSs fail to recognize different assaults along with zero-day attacks and decreasing FAR. This in the end brings about an interest for a productive, precise, and practical NIDS to give solid security to the network [11].

This survey paper is different from the studied papers in the following ways; (i) A Deliberate article choice cycle is followed for this article to attain more centered articles around NIDS configuration by utilizing simulated intelligence devices. Different examinations assessed the overall IDS framework without utilizing the precise methodology. (ii) Our review primarily inspected the articles by using deep learning-based NIDS. The remainder of the paper is coordinated as follows: Section 2 depicts the literature review in the form of Table 1 as well as in the taxonomy form of articles studied to accomplish this survey paper. Section 3 explains the DL methodologies embraced in this paper. Section 4 defines the datasets and evaluation metrics used in the context of papers studied in the form of Tables 2 and 3. Identified research challenges & future scopes in the current domain are given in Section 5. Lastly, Section 6 provides the conclusion of this article.

2. Literature Review

The taxonomy of DL-based NIDS is depicted in Figure 1 and a detailed classification of various proposed methodologies, and datasets, along with their pros and cons is shown in Table 1. In addition, DL acts as a subgroup of ML that comprises several hidden layers to attain the significance of a deep network and provides more efficient results by learning meaningful features from its own, deep structure to produce an output. Based on the literature studied, the dataset used by researchers along with their performance parameters are tabulated in Table 2. Various DL techniques adopted are as follows:

- ***RNN:*** Recurrent Neural network primarily intends to model sequence data by extending the traditional feed-forward neural network(NN) capabilities. In this, a combination of hidden, input, and output layers is present, where hidden layers represent memory elements. To obtain a decision, every unit of RNN depends on its present input as well as the output of the preceding input.
- ***AE:*** Autoencoder is a different kind of DL technique that is based upon unsupervised NN that bothers the principle of identical output as much closer to input by best feature learnings. Output and input layers are of the same dimension in this technique, while hidden layers are kept smaller in comparison to the input layer.

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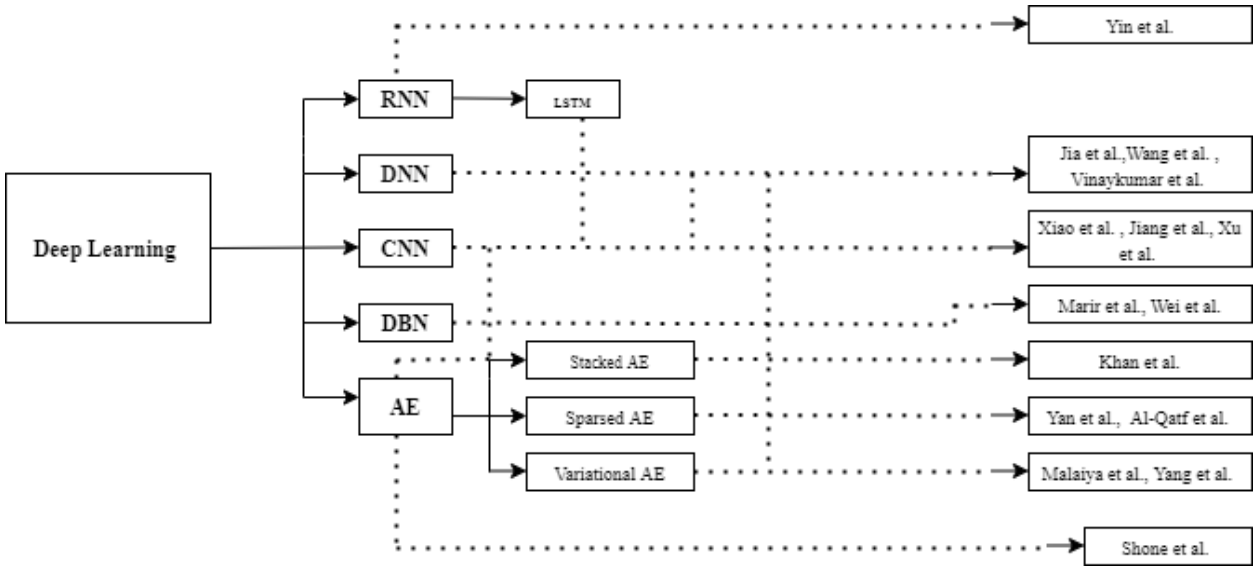


Figure 1: DL-based NIDS taxonomy

- ***DNN:*** Deep Neural Network allows model learning capabilities by taking advantage of multiple layers, mainly in modeling nonlinear functions of complex types. In this model, model capability can be enhanced by increasing the number of hidden layers.
- ***DBN:*** Deep Belief Network is generated by the stack of various 2-layer models (hidden and input layers) which possess bidirectional flow of data. In this technique, every node within a layer is attached to every node in succeeding and preceding layers, but not connected within one layer in an unsupervised manner.
- ***CNN:*** Convolutional Neural Network structure is mostly applicable to those situations where there is a requirement to store data in array form. It comprises one input layer, stacks of pooling layers and CNN for extraction of efficient features, fully connected layers, and lastly a softmax classifier in the classification layer. For NIDS, it has applicability for classification and efficient supervised meaningful extraction of features.

Table 1: Classification of various NIDS Methodologies adopted for this Study

Author	***Methodology***	***Dataset***	***Pros***	***Cons***
Yin et al. [1]	RNN	KDD CUP: A-83.28%	Higher intrusion detection accuracy	Complex model and it requires high training time.
Shone et al. [2]	Non-Symmetric AE	KDD Cup 99: A-97.85%, P-99.99%, R-97.85%, F1-	Efficient feature selection	Weaker detection accuracy for minority classes of attacks.

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		98.15%, FAR-2.15%. NSL-KDD: A-85.42, R-85.42, P-100, FAR-14.58, F1-87.37%..	Reduced model complexity	
Jia et al. [3]	DNN	KDD Cup 99: A-0.9995, MAR-0.0005, FDR-0.0003, R-0.9997, P-0.997, F1-0.9997	Superior performance in comparison to ML-based models	Older datasets are used for evaluating proposed model performance.
Wang et al. [4]	DNN	NSL-KDD: A-99.75%, P:89.50%, R-25.38%, FAR-0.01%, F1-39.53%	Higher accuracy achieved	No real-time environment is taken into consideration to detect attacks.
Yan et al. [5]	Sparse AE	NSL-KDD: A-99.35%, DR-99.01%, FAR-0.13%	Efficient feature extraction to build an efficient NIDS.	Older dataset
Xu et al. [7]	NN using GRU	KDD 99: A-99.98%, R-99.42%, FAR-0.05%. NSL-KDD: A-99.55%, R-99.31%, FAR-0.84%.	GRU is used as the main memory for RNN to build an efficient NIDS model.	The model shows a lower rate of detection of minority class attacks (e.g., U2R, R2L).
Al-Qatf et al. [8]	Sparse AE	NSL-KDD: A-84.96%, P-96.23%, R-76.57%, F1-85.28%.	Effective novel model proposed based on Sparse AE	Proposed Model performance against minority classes of attack is not presented
Marir et al. [9]	DBN	NSL-KDD: AUROC-0.9856, P-0.9727, R-0.9217, F1-0.9465. UNSW-NB15: AUROC-0.9800, P-	Abnormal attacks are detected in a distributed fashion. A voting mechanism is	The complex proposed model requires high training time.

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		0.9047, R-0.9721, F1-0.9372. CIC-IDS2017: AUROC-0.9630, P-0.9040, R-0.9565, F1-0.9295.	preferred for prediction in this model.	
Papamartizivanous et al. [10]	STL and Sparse AE	KDD Cup 99: A-77.99%	Autonomous NIDS model by combining STL and Sparse AE.	The proposed model is incapable of detecting U2R and R2L attacks efficiently.
Khan et al. [12]	Stacked AE	KDDCup99: A-99.996% UNSW-NB15: A-89.134	Support for binary and multiclass classification of attacks.	NB15 model detection accuracy decreased by about 10%.
Xiao et al. [13]	CNN with PCA and AE	KDD Cup 99: A-94%, DR-93.0%, FAR-0.5%	Effective NIDS model in which feature extraction is evaluated using AE and PCA.	Lower detection rate of R2L and U2R attacks.
Vinaykumar et al. [14]	DNN	KDD Cup 99: A-81.1%, FPR-22.9%, TPR-97.8%. NSL-KDD: A-68.2, FPR-49.6, TPR-91.9%. WSN-DS: A-93.4, FPR-14.7, TPR-99.8%. UNSW-NB15: A-72.9%, FPR-37.6%, TPR-95.4%. CIC-IDS2017: A-88.5%, FPR-16.1%, TPR-90.5%.	Hybrid and scalable model for real-time monitoring of network traffic.	Complex proposed model

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Wei et al. [15]	DBN	NSL-KDD: A-82.36%	The model is optimized by combining various optimization models (i.e., Fish Swarm, Particle Swarm, & Genetic Algorithm).	Higher training required
Malaiya et al. [16]	FCNs, Variational AE	UNSW-NB15: A-100%, P-100%, R-100%, F1-100% CIC-IDS2017: A-100%, P-100%, R-100%, F1-100%	Various models for NIDS were proposed using FCN by considering newer and older datasets.	Greater computational cost. Absent of best detection model while considering minority classes of attacks.
Jiang et al. [17]	Hierarchical model based on BiLSTM and CNN	NSL-KDD: A-83.58%., P-84.49%, R-84.49%, F1-92.15%. UNSW-NB15: A-77.16%	Class imbalanced problem is effectively tackled by SMOTE	Complex model
Yang et al. [18]	DNN and Variational AE	KDD Test 21: A-80.30%, DR-95.19%, F1-86.92%, FPR-18.22%. UNSW-NB15: A-93.01%, DR-91.94%, F1-93.54%, FPR-5.67%.	An efficient model is proposed on the basis of supervised adversarial VAEs with DNN	For the UNSW-NB15 dataset, the detection accuracy of minority classes of attack was not considered.
Yu et al. [19]	DNN and CNN	NSL-KDD: DR-94.07%, FPR-1.18%, P: 90.37%, F1-92.99%. UNSW-NB15: A-92%, FAR-6.39%.	CNN and DNN models are considered for reducing dimension	Application-limited model as it required labeled data for learning.

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			and effective feature extraction.	
Andersini et al. [20]	CNN and Multi-stage AE	KDD Cup 99: A-93.00%, F1-95.50% UNSW-NB15: A-93.40%, F1-95.29% KDD Cup 99: A-97.90%, F1-94.93%	Higher performance is achieved by using a multistage model.	The model was not tested to detect minority classes of attacks.

Table 2: Datasets and Performance Metrics Used in Literature

Articles	Datasets						Performance Metrics							
	KDD Cup'99	Kyoto	CIC-IDS2017	NSL-KDD	UNSW-NB15	Others	Accuracy (A)	Precision (P)	Recall (R)	F1-Score(F1)	False Alarm Rate(FAR)	ROC	True Positivity Rate (TPR)	Others
Yin [1]	✓	×	×	×	×	×	✓	×	×	×	×	×	×	×
Shone [2]	✓	×	×	✓	×	×	✓	✓	✓	✓	✓	×	×	×
Jia [3]	✓	×	×	✓	×	×	✓	✓	✓	✓	✓	×	×	✓
Wang [4]	×	×	×	✓	×	×	✓	✓	✓	✓	✓	×	×	×
Yan [5]	×	×	×	✓	×	×	✓	×	✓	×	✓	×	×	×
Xu [7]	✓	×	×	✓	×	×	✓	×	✓	×	✓	×	×	×
Al-Qatf [8]	×	×	×	✓	×	×	✓	✓	✓	✓	×	×	×	×
Marir [9]	×	×	✓	✓	✓	×	×	✓	✓	✓	×	✓	×	✓
Papamartizivanous [10]	✓	×	×	×	×	×	✓	×	×	×	×	×	×	×
Khan [12]	✓	×	×	×	✓	×	✓	×	×	×	×	×	×	×
Xiao [13]	✓	×	×	×	×	×	✓	×	✓	×	✓	×	×	×
Vinaykumar [14]	✓	✓	✓	✓	✓	✓	✓	×	×	×	✓	×	✓	×
Wei [15]	×	×	×	✓	×	×	✓	×	✓	×	✓	×	×	✓
Malaiya [16]	×	×	✓	×	✓	×	✓	✓	✓	✓	×	×	×	✓
Jiang [17]	×	×	×	✓	✓	×	✓	✓	✓	✓	×	×	×	×
Yang [18]	×	×	×	✓	✓	×	×	✓	✓	✓	✓	×	×	×

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Yu [19]	×	×	×	✓	✓	×	✓	✓	✓	✓	✓	×	×	×
Andersini [20]	✓	×	✓	×	✓	×	✓	×	×	✓	×	×	×	×

3. Benchmark Datasets

As per the literature studied, there are several datasets used by various researchers in the current domain. Out of which, some most popular datasets used by researchers along with their kind of attacks covered are tabulated in Table 3 as follows:

Table 3: NIDS Datasets & Category of Coverage Attacks

Dataset	**Denial of**	**U2R**	**R2L**	**Probe**	**Unknown**	**Known**	**Exploits**	**Backdoors**	**Generic**	**Fuzzers**	**Reconnaissa**	**Port Scans**	**Worms**	**Shellcode**	**Brute Force**	**Botnet**	**Infiltration**	**DDoS**	**Web**	**Heartbleed**
CIC-IDS2017	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	✓
UNSW-NB15	✓	×	×	×	×	×	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×	×	×	×
Kyoto	×	×	×	×	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×
NSL-KDD	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
KDD 99	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×

4. Performance Parameters

This part describes the generally used performance metrics which are based on various attributes for calculating DL methodologies performance for NIDS, which are as follows:

Precision: It is defined as the ratio of accurately predicted attacks to all predicted samples as attacks as shown in Eqn.1.

$$P = \frac{TP}{TP+FP} \quad (1)$$

Recall: Also called the rate of detection (DR) & It is represented as the ratio of all accurately classified attacks to actual attack samples as shown in Eqn.2.

$$R = \frac{TP}{TP+FN} \quad (2)$$

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Accuracy: It is defined as the ratio of accurate classified data instances to the total count of data instances & also called detection accuracy as shown in Eqn. 3.

$$A = \frac{TP+TN}{TP+FN+TN+FP} \quad (3)$$

FAR: It is also called FPR & can be calculated as the ratio of falsely predicted attack data instances to all attack samples which are normal as shown in Eqn. 4.

$$FAR = \frac{FP}{FP+TN} \quad (4)$$

F1-Score: It is represented as a statistical approach for determining the system accuracy by considering both P & R of the system as shown in Eqn. 5.

$$F1 = 2\left(\frac{P*R}{P+R}\right) \quad (5)$$

- TruePositive(TP): Data accurately predicted as known attacks by the adopted classifier.
- FalsePositive(FP)FP:Data falsely classified as an attack.
- FalseNegative(FN):Data falsely predicted as normal data instances.
- TrueNegative(TN):Data correctly classified as normal data instances.

5. Conclusion

This study primarily focused on the literature review of the NIDS mechanism based on DL methodologies to provide attention to new practitioners and researchers with the required knowledge, progress, and recent trends in the current field. In this work, firstly, the NIDS concept along with the need for NIDS is discussed and its various classification methodologies are extensively elaborated based on the literature studied. Sequentially, the DL-based techniques of each paper are defined and the pros and cons of each are defined. Based on literature studies, recent trends suggest that by adopting DL-based NIDS effectiveness and performance can be improved by reducing FAR reduction rate and improving DR. This study also highlights that potential research challenges must be required to address in a real-time environment for NIDS to improve NIDS performance. For working further in the same domain, we will use this meaningful information to design an efficient, novel DL-based NIDS for improving detection rate while reducing FAR to detect intruders in a real-time environment.

6. Future Scopes

Based on this study, we suggest the following future works in DL-based NIDS research which are as follows:

- **Effective NIDS system:** Recent literature expresses its incapabilities in zero-day attack detection with a high FAR. For this, NIDS's effective performance can be enhanced by using a benchmark updated, balanced, and systematic dataset.

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- **Complex Models:** Recent literature also expresses that adopting DL-based techniques can effectively improve the performance of NIDS but these models require high computational power and are complex which results in decreasing its detection accuracy in efficient time. For this, cloud-based services and platforms can be used for proposed model training.
- **DL-based Algorithms:** Another solution for improving detection accuracy in DL-based algorithms by performing intelligent and effective feature engineering by selecting only key features to reduce model complexity as well as by using reduced resources in computing in a live environment.
- **Selection of Efficient Dataset:** As per the literature studied, we found that approx. 75% of methodologies adopted in DL-based domains are either performed on KDDCup 99 or NSL-KDD datasets. To perform intrusion detection in a real-time environment, updated and balanced datasets must be taken into consideration to improve the effectiveness of the proposed model.
- **Coverage of minority class of attacks:** Several research papers studied in literature were unable to cover minority classes of attacks efficiently. For this, a hybrid model can be devised that considers efficient features engineering with updated datasets to cover these categories of attacks in an organized manner.

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A Comparative Analysis of Machine Learning Algorithms for Alzheimer's Disease Detection

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Abstract

Alzheimer's Disease is a brain disorder in which brain cells are damaged due to the deposition of certain proteins, causing interference between neurons which results in degeneration of brain cells over time. It is caused due to both environmental and genetic factors. It mostly affects people over 65 or older, where newer case studies show an increasing number of cases every year. The early stages of Alzheimer's disease often go unnoticed; however, it gradually worsens over time. Symptoms include memory loss, problems with language, disorientation, and impaired motor skills, difficulty in finding words, which lead to dehydration, malnutrition, and infection, ultimately resulting in death. Therefore, early detection of Alzheimer's disease is important to slow its progression and develop different treatment strategies.

The modern approach and more effective techniques to tackle these problems are machine learning algorithms, Machine Learning algorithms can be used to train the model that can classify and analyze the common patterns in patient data to detect Alzheimer's disease progression. The most common databases that are used for training and using ML are OASIS & ADNI. In this literature survey, we have drawn a comparison between the performance of different machine learning algorithms from previous studies. Where we found that detection through machine learning holds a promising future especially, when using a combination of algorithms together.

The paper elucidates the preeminent algorithm presently recognized for the diagnosis of Alzheimer's disease.

Keywords: Alzheimer's Disease, Neuronal Interference, Machine Learning Algorithms, Healthcare

Introduction

Alzheimer's disease (AD) represents a significant global health challenge, being a widespread neurodegenerative disorder impacting millions [1]. Early and accurate diagnosis is crucial for

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effective intervention and patient care, given the progressive nature of Alzheimer's, leading to challenges in daily activities and increased caregiver dependence [1]. The associated emotional and financial burdens on families and society are considerable, compounded by the absence of a cure and the focus on symptom management and improved quality of life [1].

The traditional manual approach to AD detection relies on subjective cognitive assessments using questionnaires, a method laborious and dependent on the expertise of healthcare professionals [1]. In recent years, a paradigm shift has occurred, with a growing emphasis on the application of machine learning algorithms for predicting Alzheimer's disease. These algorithms leverage diverse datasets and computational models to enhance the accuracy and efficiency of early detection [5].

The paper is organized as follows. Section two presents a literature review and presents a comparative analysis of machine learning algorithms and section four concludes.

Literature Review

Alzheimer's disease is a progressive neurodegenerative disorder that primarily affects older adults. It is the most common cause of dementia, a group of brain disorders that result in the loss of intellectual and social skills. Alzheimer's disease typically begins with mild memory loss and confusion, which gradually worsen over time. Other symptoms may include difficulties with language, changes in mood and behavior, disorientation, and problems with reasoning. Therefore, early detection of AD is necessary. The current method for AD detection is manually based on a 30-point questionnaire that assesses various cognitive functions, including memory, attention, and language. The primary indicator for predicting the progression of the disease is the MMSE (Mini-Mental State Examination) score. This score tends to decline over time as the individual is affected by the condition. It's important to note that individuals with Mild Cognitive Impairment (MCI) are at a heightened risk of developing dementia. When the core symptoms of MCI, such as memory loss, become more pronounced, the likelihood of the condition progressing to full-blown dementia increases. However, manual detection is purely based on the experience of the person conducting it. In recent years machine learning algorithms have paved their way to early AD detection.

A literature review has been carried out to study the state-of-the-art techniques, find the gaps, and present current challenges. IEEE, Springer, Science Direct & Wiley databases were explored. Some of the important studies from the duration of 2020 to 2023 have been selected and presented in Table 1.

Upon meticulous comparison of various papers, the Convolutional Neural Network (CNN) emerges as the frontrunner, demonstrating the most promising outcomes among competing

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algorithms. Notably, its efficacy remains robust even when subjected to rigorous testing with and without filters. Hence, it is imperative to accord CNN greater prominence in future endeavours, particularly when considering combinations of algorithms.

Table 1: Literature Review

Year	Algorithm used	Dataset	Accuracy	Limitation
2023	(CNN), Inception V3, DenseNet	The dataset was obtained from Kaggle, consisting of 6,400 records. Out of these, 5,121 records were used for training the model, while the remaining 1,279 were used for testing.	The accuracy percentage for the CNN model is reported as 97%. Whereas for Inception V3 and DenseNet it is 92% & 93% respectively.	The model has not been tested for the synergy of combining all three algorithms, limiting our exploration of ensemble learning.
2023	Support vector machine (SVM) Random Forests (RF) Feed-Forward Neural Networks (FNN)	Kaggle's Alzheimer Dataset 70% Training Data 30% Testing Data	FNN model (88%) has more accurate predictions compared to SVM (86%) and RF (87%)	MR Scans could be used in the dataset to get a more accurate assessment.

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2023	1. Logical Regression 2. Naïve Bayes 3. Support Vector Machine 4. Random Forest 5. Decision Trees	OASIS-2: Longitudinal MRI Data of 150 persons	RF has the highest accuracy (93.69%) in prediction compared to Naïve Bayes (88.29%), SVM (91.89%), Decision Tree (83.78%) and Logistics Regression (61.5%).	Family history, accidents, genetics, etc. are not included which can enhance the dataset for better accuracy.
2022	Support Vector Algorithm (SVM) Random Forest (RF)	A 3D Convolutional Neural Network (CNN), Gradient Boosting model	ADNI (Alzheimer's Disease Neuroimaging Initiative), NACC (National Alzheimer's Coordinating Center), IDs of patients and scans Demographics varied between ADNI and NACC, including age, gender, and APOE4 prevalence.	The deep-learning model achieved AUCs of 87.59 for CN vs. the rest, 62.59 for MCI vs. the rest, and 89.21 for AD vs. the rest on the ADNI test set.
2022	Convolutional Neural Network (CNN)	Decision trees, Random forests, Support vector machines (SVM), and knearest neighbors (KNN), DL.	ADNI dataset	The deep model outperforms shallow algorithms when combining all three modalities (imaging, electronic health records, and single nucleotide polymorphisms).

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2022	Intensity Normalization, Contrast Enhancement, Denoising, Brain Extraction and Skull Stripping, Data Augmentation	Support Vector Machine(SVM), Decision Tree	Alzheimer's disease Neuroimaging Initiative (ADNI)	For SVM the accuracy comes out to be 85%. The decision tree shows an accuracy of 83%.
2022	A 3D Convolutional Neural Network (CNN), Gradient Boosting model	Gaussian filter, Otsu thresholding, Prewitt edge detection, GLCM, Fuzzy C-means, CNN	OASIS-3 (1000 patients) MRI images age from 42-95yrs, Dataset contains 2842 MR sessions which include T1w, T2w, FLAIR, ASL, SWI, time of flight, resting-state BOLD, and DTI sequences. Many of the MR's	90.25% accuracy, 85.53% sensitivity
2021	Decision trees, Random forests, Support vector machines (SVM), and knearest neighbors (kNN), DL.	ADNI dataset	The deep model outperforms shallow algorithms when combining all three modalities (imaging, electronic health records, and single nucleotide polymorphisms).	One significant obstacle to the widespread use of deep learning models in clinical decision-making is the absence of clear and established techniques for interpreting these complex models.

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2021	Support Vector Machine(SVM), Decision Tree	Alzheimer's disease Neuroimaging Initiative (ADNI)	For SVM the accuracy comes out to be 85%. The decision tree shows an accuracy of 83%.	The results were not compared by combining both brain MRI scans and the psychological parameters.
2021	Gaussian filter, Otsu thresholding, Prewitt edge detection, GLCM, Fuzzy C-means, CNN	OASIS-3 (1000 patients) MRI images age from 42-95yrs, Dataset contains 2842 MR sessions which include T1w, T2w, FLAIR, ASL, SWI, time of flight, resting-state BOLD, and DTI sequences. Many of the MR's	90.25% accuracy,85.53% sensitivity	Using a complex model like CNN on a limited dataset can lead to overfitting. The algorithm needs to be tested with other data sets.

During the literature review, it was observed that various machine-learning models have been used to detect AD. These include CNN, SVM, RF, DT, IV3, DNN, NB and LGG. It has been observed that CNN has the best accuracy of 97%. It has also been observed that limited work has been done in AD using ensemble techniques.

Table 2: Comparative analysis of machine learning algorithms for Alzheimer detection

Models	**Description**	**Accuracy**
CNN	Convolutional Neural Network (CNN) is a machine learning model that uses convolutional layers to automatically learn hierarchical representations, enabling effective pattern recognition in visual data. They are specifically designed for image recognition.	97%, 90.25%, Using CNN along with SMOTE and Gaussian Filter 91.65%
SVM	Support Vector Machine (SVM) is used for classification and regression. While not inherently a	85%,86%, 91.89%, 92%,

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	deep learning algorithm, it can be integrated into deep learning frameworks for improved performance.	
RF	Random Forest (RF) is a classic ensemble learning method that constructs multiple decision trees to enhance accuracy. While not a deep learning algorithm, it can complement deep models in hybrid architectures.	93.69%, 87%, 83%
DT	Decision Tree (DT) is a non-deep learning algorithm that recursively splits data based on features to make decisions. While distinct from deep learning, it can be combined with deep models for hybrid solutions.	83 ±1%,
IV3	InceptionV3 (IV3) is a deep convolutional neural network architecture designed for image classification and recognition. It employs inception modules with diverse kernel sizes to capture hierarchical features efficiently.	92%
DN	DenseNet (Densely Connected Convolutional Network) is a deep learning architecture that connects each layer to every other layer in a feedforward fashion. It encourages feature reuse, reduces vanishing gradient problems, and enhances training efficiency in neural networks.	93%
FNN	Feedforward Neural Network (FNN) is a fundamental deep learning model where information moves in one direction—from input to output. It consists of layers of interconnected neurons, with no feedback loops.	88%,
NB	Naive Bayes is a probabilistic machine learning algorithm based on Bayes' theorem. It assumes independence between features and calculates the	88.29%

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	probability of class labels given input features for classification tasks.	
LG	Logistic Regression is a statistical method used for binary classification. It models the probability of an event occurring based on input features, applying a logistic function to predict outcomes.	61.5%

Conclusions

Alzheimer's disease, a progressive neurodegenerative disorder, poses a significant challenge to individuals, families, and healthcare systems worldwide. First identified by German psychiatrist and neuropathologist Alois Alzheimer in 1906, the condition is characterized by the gradual deterioration of cognitive functions, including memory loss, impaired reasoning, and changes in behavior. Alzheimer's primarily affects older adults, with the majority of cases occurring after the age of 65, though early-onset forms exist. This work reviews the machine learning algorithms used in AD detection. The work presents a comparative analysis of various Alzheimer's disease prediction studies and reports that CNN has the best accuracy of 97%.

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BIOSYNTHESIS AND APPLICATION OF SILICA-COATED ZINC OXIDE NANOCOMPOSITE FOR REMOVAL OF LEAD (II) IONS FROM SIMULATED WASTEWATER

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Abstract

The current work evaluated the capacity of Silica-coated zinc oxide nanocomposite (Si-ZnO NC) to remove Pb (II) ions from simulated wastewater. Si-ZnO NC was fabricated utilizing a green synthesis strategy and co-precipitation method. The produced Si-ZnO NC was characterized by FTIR, XRD, SEM-EDX and BET analysis. The influence of various operating variables like- pH, initial metal ion concentration, adsorbent dose, contact time and temperature were investigated on Pb (II) removal. The maximum removal efficiency of Si-ZnO NC for Pb (II) ions removal was found to be 94.6% at pH 6.5, equilibrium time 60 min, and adsorbent dose. The adsorption data was found to follow pseudo second order kinetics and Langmuir isotherm model. Thermodynamic variables including enthalpy change (ΔH^0), free energy change (ΔG^0), and entropy change (ΔS^0) were computed and results revealed that adsorption is spontaneous and endothermic. Regeneration assessment was also carried out using 0.1M NaOH as desorbing agent.

Keywords: Si-ZnO NC, Pb (II) adsorption, isotherm models, kinetics, reusability

1. Introduction

There is not enough water in many nations to meet human demand due to rapid industrialization and population growth. Most of the available water resources are severely polluted due to addition of industrial effluents and sewage. Heavy metals are among prime sources of polluted water, they are highly harmful even at modest levels. Therefore, treating wastewater as a part of water security strategy has become a top priority for nations [1]. Lead, Pb (II) is among the most hazardous metals that can end up in the environment as a consequence of various industrial processes. In addition, batteries, pipelines, artworks, lead plates, technological goods and healthcare devices have all been contain Pb [2]. Pb (II) ions get attach to red blood cells (RBCs) and eventually accumulate into bones. Humans adsorb around 20-80% of inorganic Pb by ingestion and 5-15% by inhalation [3]. Pb (II) exposure harm human kidneys, liver, nervous system and reproductive system, which leads to cancer, irritability, anemia, weakness of muscles, kidney dysfunction and mental impairment especially in children [4]. Due to its harmful properties, Pb is crucial for the well-being of society and environment to remove it from water & wastewater. Various approaches including ozonation, membrane filtration, ion exchange, biological treatment, adsorption and electrochemical

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techniques have been documented for removing heavy metals from wastewater [5-8]. Owing to the health risks, operational expenses and production of hazardous byproducts associated with previously mentioned technologies, adsorption has been proposed as an effective, economical and flexible technique. The effectiveness of adsorption is greatly affected by adsorbent properties and process conditions [9]. The genesis of innovative nano-adsorbents to eliminate harmful metal ions from aqueous environment has drawn interest because of recent advancements in field of nanotechnology. Nanoparticles of Zinc oxide (ZnO) have shown good efficiency in water treatment and environmental remediation owing to their band gap, low toxicity photocatalytic potential, antibacterial action and optical properties [10]. Additionally, Silicon dioxide (SiO_2) nanoparticles have also shown good potential for selective Pb (II) ions removal because of their lesser toxicity, ease of surface modification, low cost of production and porosity [11]. Different methods are used to prepare these adsorbents but they are labor-intensive, chemically demanding and expensive. Thus, it is desirable to produce adsorbents by ecologically and economically sound processes. In this work, novel Si-ZnO NC was fabricated using biogenic green synthesis approach. Si-ZnO NC was prepared using rice husk extract as silica source. Rice husk or rice hull is the outer layer of rice grain and a by-product of rice milling. Despite being a byproduct of agriculture, rice husk is regarded as a good source of silica [29]. Though some of the work has been conducted using Si-ZnO NC as adsorbent but the possibilities of heavy metal removal are yet to be explored [30,31]. So, in this research we have investigated the removal of Pb (II) ions using Si-ZnO NC through batch mode method. Analytical methods like XRD, FTIR, SEM-EDX and BET were employed to evaluate the functionality, bonding, formation and morphology of Si-ZnO NC. The impact of pH, metal ion concentration, nanocomposite dose, contact time and temperature were conducted to evaluate Pb (II) ions removal on surface of Si-ZnO NC. Various isotherms and kinetic models were also utilized to estimate the effectiveness and maximum sorption capacity.

2. Materials and Methods

2.1 Chemicals used

Every chemical utilized was of analytical grade and bought from CDH Ltd. Dilute hydrochloric acid (dil. HCl), Sodium hydroxide (NaOH) and Zinc nitrate hexahydrate $(ZnNO_3)_2$. $6H_2O$ were used in Si-ZnO NC synthesis. Initial solution of Pb (II) was made with $Pb(NO_3)_2$. The Rice husk utilized in this study was collected from a nearby mill at Bhupani Sec-88 Faridabad, India as a processing waste.

2.2 Synthesis of Si-ZnO NC

Si-ZnO NC was synthesized via modification of already reported method [12]. Washing of rice husk was first done with tap water. Afterward, it was washed with dil. HCl followed by deionized water. It was then sundried and ground to make a powder for further usage. 25g of powdered rice husk was stirred with 2M NaOH solution at 80°C for 3 hours. The obtained extract was then treated with 0.1 M zinc nitrate hexahydrate solution in 1:1 ratio with constant stirring at 80°C. Mixture obtained was stirred for 24 hours, centrifuged and washed with deionized water. After being washed, Si-ZnO NC was dried in a hot air oven and stored for later adsorption tests.

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2.3 Characterization of prepared Si-ZnO NC

The Fourier transform infrared analysis (Shimadzu IR AFFINITY-I, Japan) was carried out using KBr powder under 4000 - 400 cm^{-1} range of spectrum array to identify the surface functionalities of the nanocomposite. X-ray diffraction (XRD) analysis was completed using Panalytical X Pert Pro having Cu K_α X-ray radiation within 20 - 80° and 2°/min scanning rate. The surface organization and configuration analysis of nanocomposite were investigated by Field Emission Scanning Electron Microscope (FESEM) and Energy Dispersive X-ray spectroscopy respectively with FESEM Carl Zeiss (Merlin Compact 6073, Germany). The specific surface area and pore size distribution of fabricated nanocomposite were examined with BET analyzer (BELSORP-MaxII) at 77.35 K.

2.4 Pb (II) removal experiments

Batch mode study was performed for sequestration of Pb (II) ions by Si-ZnO NC from simulated wastewater. 25 mg of Si-ZnO NC was put in a 250 mL conical flask holding 50 mL metal solution, pH calibration was done by adding 0.1 M NaOH and 0.1 M HCl to attain adsorption equilibrium. Thereafter, this mixture was shaken for 120 min at 200 rpm at 25° C in a closed orbital shaker. The adsorption conditions including pH, Pb (II) concentration, temperature, time and nanocomposite dose were optimized through experiments. pH of solution was changed from 2-10 to examine the influence of pH. Through experimenting with an optimized pH, the influence of contact time (10-180 min) was determined. Adsorption study was carried out by varying initial concentration of Pb (II) ions (10-60 mg/L), temperature (15-45°C) and adsorbent dose (0.1-1 g/L). After adsorption, spent adsorbent was centrifuged off and remaining amount of Pb (II) in supernatant examined using Microwave Plasma - Atomic Emission Spectroscopy (Agilent, 4210 MP-AES). Adsorption capacity (mg/g) and removal efficiency (%) were calculated using Eq (1) and (2) respectively.

$$\text{Adsorption capacity } (q_e) = \frac{(Co - Ce)V}{m} \quad (1)$$

$$\text{Removal efficiency } (\%) = \frac{Co - Ce}{Co} \times 100 \quad (2)$$

Where C_o = Initial Pb (II) ions concentration (mg/L),
C_e = Final Pb (II) ions concentration (mg/L),
m = Mass of Si-ZnO NC (g),
V = Solution volume(L).

3. Results and Discussion

3.1 FTIR (Fourier Transform Infra-Red) Spectroscopy

FTIR pattern of Si-ZnO NC with characteristic peaks is shown in Fig. 1. Absorption peaks at 3738.21 cm^{-1} and 3381 cm^{-1} denote possible existence of hydroxyl group on nanocomposite surface. Weak peaks at 2923.88 cm^{-1} and 2852.91 cm^{-1} corresponds to methylene group's C-H stretching vibration in Si-ZnO NC. The signature peak at 1649.48 cm^{-1} indicates C=O molecule stretching whereas distinctive peaks at 1481.22 cm^{-1} and 1406.8 cm^{-1} are representative of C-H bending vibrations [13]. Si-O stretching vibrations are responsible for a prominent peak at 1003.31

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cm^{-1}, confirming the incorporation of silica into the nanocomposite as synthesized. FTIR peak at 537.31 cm^{-1} consigned to presence of Zn-O-Zn stretching, thereby confirming the fabrication of ZnO nanoparticles.

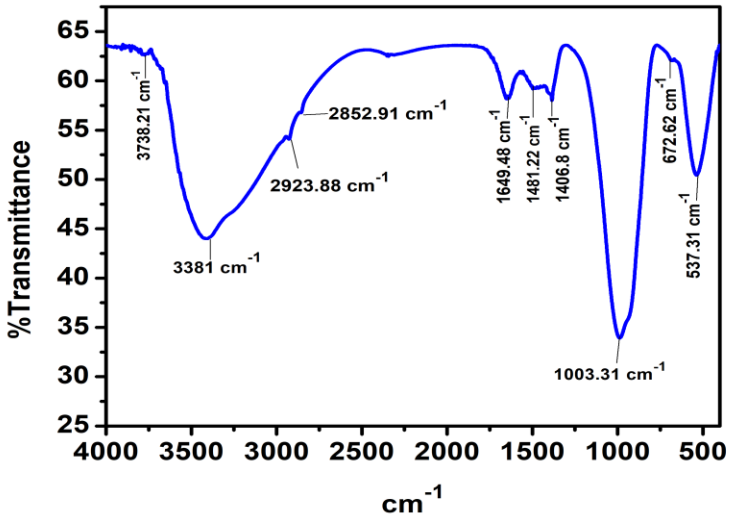
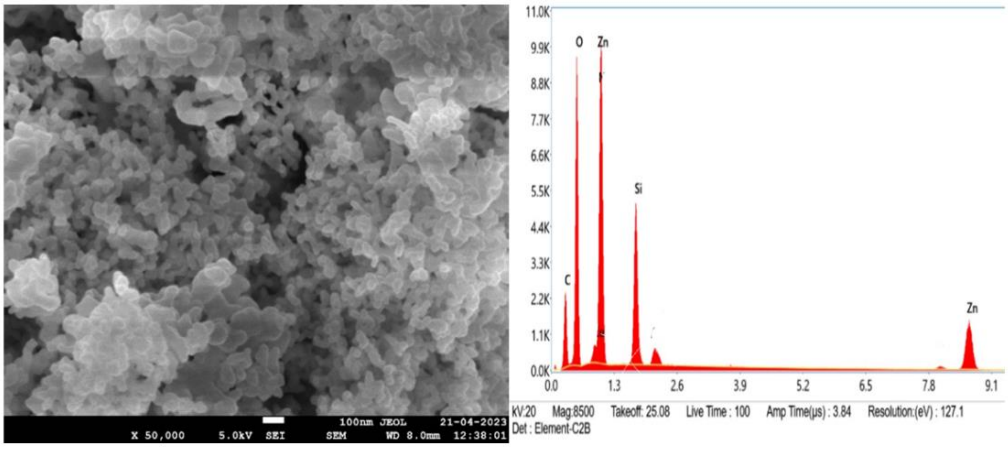


Fig 1: FTIR analysis of Si-ZnO NC

3.2 SEM-EDX analysis

SEM analysis had been carried out to explore surface morphology of nanocomposite (Fig. 2a). It revealed that the bio-fabricated nanocomposite possesses roughly spherical particles in agglomerated form. The presence of porous surface and small globule like structure that facilitates for diffusion of adsorbate can also be seen. Fig. 2b represents the elements and spectrum of Si-ZnO NC from EDX analysis. The EDX spectrum revealed that O (33.2%), C (8.8%), Zn (41.6%) and Si (16.4%) are the major components in the obtained nanocomposite.



(a) (b)

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Fig 2: (a) SEM analysis (b) EDX analysis

3.3 XRD (X-Ray Diffraction) analysis

Fig. 3 depicts the XRD spectra of Si-ZnO NC. Diffraction peak at 2θ = 21.22º is distinctive for silica. The XRD pattern of synthesized nanocomposite showed a broad hump suggesting amorphous nature. Since, rice husk is organic matter and silica was extracted from the waste rice husk, noise in the XRD pattern is indicative of amorphous nature of adsorbent [14]. The amorphous materials generally have high surface area and increase the force of interaction between adsorbent and substrate material which leads to increase in overall adsorption efficiency. The main diffraction peaks at 2θ = 31.08º, 36.06º, 46.16º, 56.23º and 67.76º validated the existence of zinc oxide [15]. Thus, result verified that the synthesized nanocomposite contained zinc oxide and silica.

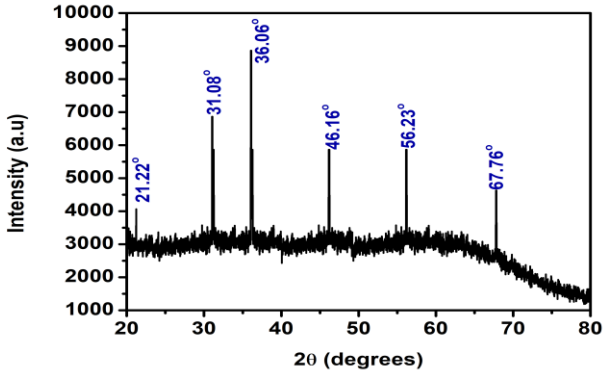


Fig 3: XRD analysis

3.4 BET (Brunauer-Emmett-Teller) assessment

The BJH pore size distribution and nitrogen adsorption - desorption plot between relative pressure (P/P^o) and volume (cm^3g^{-1} at STP) of Si-ZnO NC were analyzed using BET analyzer. Results revealed the values of BJH mean pore diameter and total pore volume to be 27.964 nm and 0.1895 cm^3g^{-1} respectively, indicating that the nanocomposite is mesoporous according to IUPAC classification. BET - specific surface area of Si-ZnO NC was determined to be 27.113 m^2g^{-1}. The isotherm curve of Si-ZnO NC showed Type III isotherm with hysteresis between P/P^o range 0 - 0.99 (Fig. 4).

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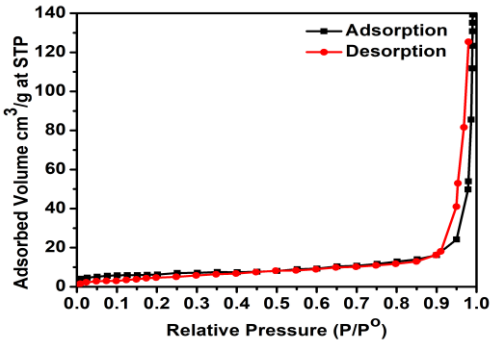


Fig 4: Nitrogen adsorption - desorption isotherm plot

3.5 Point of zero charge

The pH_{pzc} of Si-ZnO NC was found to be 4.8 as shown in Fig. 5, indicating neutral net surface charge of nanocomposite. Below this value, the surface of nanocomposite acquires positive charge and therefore favors anionic adsorption. For pH value above pH_{pzc}, negatively charged Si-ZnO NC surface makes cationic adsorption more efficient.

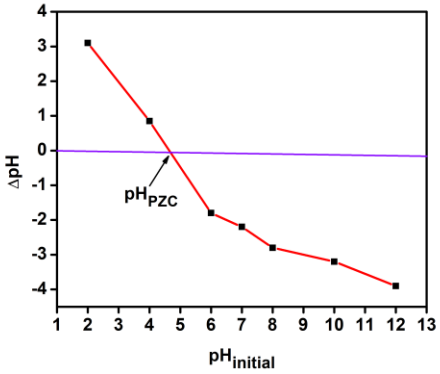


Fig. 5**:** Plot for pH_{pzc} determination of Si-ZnO NC

3.6 Effect of initial pH

The influence of pH on Pb (II) adsorption was examined for pH 2-10, keeping rest of the process conditions unchanged. Pb (II) removal efficiency increased from 21.4% to 96.9% on increasing the reaction pH from 2 to 10 (Fig 6a). Lesser removal of lead ions at pH < pH_{pzc} may be attributed to electrostatic repulsion between metal ions (Pb^{2+}, $Pb(OH)^{+}$) and protonated Si-ZnO NC surface [19,20]. At pH > pH_{pzc}, Pb (II) removal was greater owing to adsorption along with precipitation of metal ions as $Pb(OH)_2$ and deprotonation of protonated adsorbent surface. The solubility of Pb (II) ions depend on solution pH. Lead (II) is very soluble at reduced pH levels and can be found as $Pb^{2+}$and $Pb(OH)^{+}$. However, at pH values over 6, Pb (II) ions precipitate as $Pb(OH)_2$ [21]. Therefore, every adsorption investigation was done at pH 6.5 to precisely ascertain removal effectiveness of lead ions.

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3.7 Effect of initial lead concentration

The removal efficiency followed a decreasing trend on increasing lead concentration and highest removal i.e., 94.4% was recorded at 10 mg/L (Fig 6b). Reason behind this decline in removal efficiency is the availability of active sites at a constant adsorbent dose, which was greater at low lead concentration but fewer at high lead concentration [24].

3.8 Effect of Si -ZnO NC dose

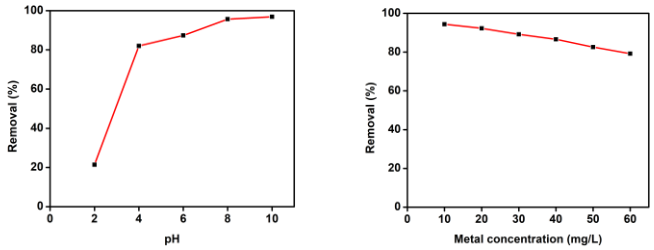
Adsorbent dose is a crucial aspect since it affects the operational budget. Fig 6c illustrates removal efficiency of Pb (II) ions at different Si-ZnO NC dose. Results suggest that effectiveness of removal rose from 72.8% to 94.6% as the Si-ZnO NC dose was raised from 0.1g/L to 0.5g/L, after which no significant change was observed on further dose increament. This can be attributed to the fact that the rise in amount of Si-ZnO NC produced huge surface area and lots of empty sites, while metal ions were limited [23].

3.9 Effect of contact time

Contact time is a prime determining component in the process of adsorption. Adsorbent-adsorbate interaction is enabled by sufficient period of contact. Impact of contact time on Pb (II) sequestration was explored for 10 to 180 min. Fig 6d clearly indicates that adsorption happened quickly during first 60 min due to enormous number of free active sites. Removal efficiency shifts from 86% to 94.6% as the time of contact increased from 10 to 60 min after which, equilibrium is reached and no more free active sites were available [25].

3.10 Effect of temperature

At optimum experimental conditions, temperature in the range of 15-45° C was examined for its effect on Pb (II) removal using Si-ZnO NC. It was observed from the results (Fig 6e) that the removal efficiency followed an increasing trend with increasing temperature. Greater removal efficiency at higher temperature indicates endothermic nature of adsorption reaction. Moreover, higher temperatures facilitate passage of ions and increase contact between metal ions and adsorbent surface [26].



(a) (b)

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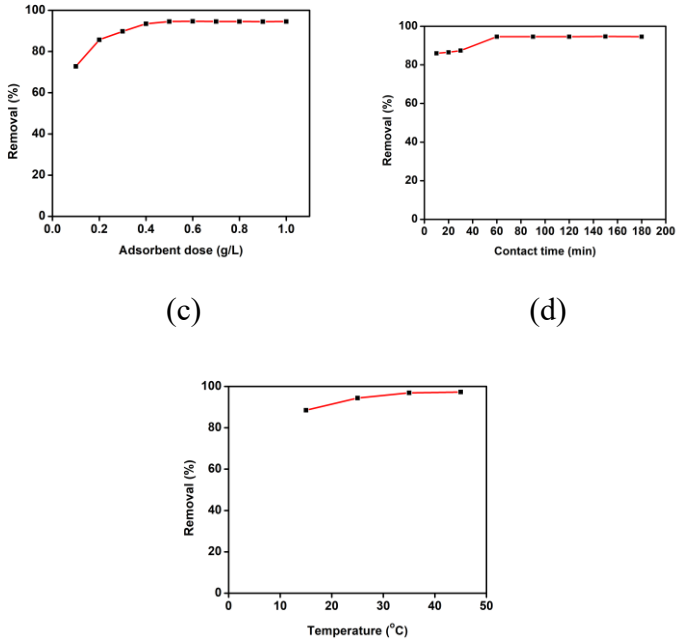


Fig 6: (a) Effect of pH on Pb (II) adsorption (b) Effect of metal concentration on Pb (II) adsorption (c) Effect of adsorbent dose on Pb (II) adsorption (d) Effect of contact time on Pb (II) adsorption (e) Effect of temperature on Pb (II) adsorption

3.11 Kinetic and isotherm analysis

Pseudo-first order (PFO) and pseudo-second order (PSO) kinetic models were examined in order to comprehend Pb (II) adsorption kinetics by Si-ZnO NC. To study PFO model, log (qe – qt) vs T(min) was drawn. Further, PSO reaction was studied to compute the adsorption rate constant from intercept of t/qt vs T(min) plot. The correlation coefficients and constants of kinetic model were computed and presented in Table 2, which suggested that adsorption kinetic reaction complies with PSO model ($R^2 = 0.9999$). This could imply that the square of no. of empty reaction sites determine exact rate of Pb (II) adsorption [16] and adsorption was the main controlling factor for Pb (II) elimination by Si-ZnO NC [17]. Langmuir, Freundlich, Temkin, and Dubinin-Radushkevich (D-R) have all been assessed in order to explore the interaction amongst Pb (II) & Si-ZnO NC. The correlation coefficients and constants for above mentioned isotherm models were computed and arranged in Table 2. Research findings for Pb (II) sequestration complemented to Langmuir model because of a greater correlation coefficient ($R^2 = 0.9943$), that implies monolayer adsorption onto Si-ZnO NC surface [18]. The value of $E < 8$ in (D-R) suggesting physisorption [19]. Langmuir isotherm's characteristic, R_L, was found to be between 0 to 1, indicating that Pb (II) ions would adsorb well on Si-ZnO NC.

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Table 1: Kinetic and adsorption isotherm models

Kinetic models	Equations	Parameters
PFO	$Log(q_e-q_t) = \log q_e - k_1/2.303\ t$	q_e: adsorption capacity at equilibrium(mg/g) q_t: adsorption capacity (mg/g) at time t (min) k_1: rate constant (min^{-1})
PSO	$t/q_t = 1/k_2q_e + (1/q_e)\ t$	k_2: rate constant (g/mg min)
Adsorption isotherms		
Langmuir isotherm	$C_e/q_e = 1/bq_{max} + (1/q_{max})\ C_e$ $R_L = 1/1+bC_o$	b: Langmuir constant (l/mg) q_{max}: maximum adsorption capacity (mg/g) R_L: separation factor
Freundlich isotherm	$lnq_e = lnk_f + (1/n)lnC_e$	$k_{f:}$ Freundlich constant n: adsorption strength
Temkin isotherm	$q_e = (RT/b)lnk_t + (RT/b)lnC_e$	b: Temkin constant R: universal gas constant (8.314 J mol^{-1} K^{-1}) K_t: equilibrium binding constant (mol/l) T: temperature (K)
D-R isotherm	$Lnq_e = lnq_m - \beta\varepsilon^2$ $\varepsilon = RTln(1 + 1/C_e)$ $E = 1/(2\beta)^{0.5}$	β: activity coefficient Ɛ: Polanyi potential E: adsorption energy

Table 2: Parameters and their values for kinetic models and adsorption isotherms

Parameters for kinetic models				
PFO	**K_1 (min^{-1})**	**q_e (mg/g)**	**R^2**	
	0.0004	7.8743	0.7374	
PSO	**K_2 (g/mg min)**	**q_e (mg/g)**	**R^2**	
	0.0167	19.308	0.9999	
Parameters for adsorption isotherm				
Langmuir	**q_m (mg/g)**	**K_L (L/mg)**	**R_L**	**R^2**
	101.42	0.4029	0.1988	0.9943
Freundlich	**1/n**	**K_f**	**R^2**	
	0.5181	27.65	0.9835	
Temkin	**K_T (L mg^{-1})**	**B_T (J mol^{-1})**	**R^2**	
	3.2632	24.64	0.9818	

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D-R	q_m (mg/g)	β (mol^2/KJ^2)	E (KJ/mol)	R^2
	56.02	0.4793	1.4707	0.83723

3.12 Thermodynamic study

Thermodynamic assessments of Pb (II) adsorption were conducted at 15°C, 25°C, 35°C, and 45°C. The thermal influence on sequestation of Pb (II) ions by Si-ZnO NC was assessed to determine adsorption related thermodynamic variables like Enthalpy (ΔH^o), Entropy (ΔS^o) and Gibbs free energy (ΔG^o). Equations shown below have been employed to determine these parameters [22]:

$$\Delta G^o = -RT\ln K_d \quad (12)$$

$$\Delta G^o = \Delta H^o - T\Delta S^o \quad (13)$$

$$K_d = C_a/C_e \quad (14)$$

$$\ln K_d = \Delta H^o/RT - \Delta S^o/R \quad (15)$$

Where C_a (mg/L) indicates quantity of lead adsorbed on Si-ZnO NC, C_e (mg/L) indicates quantity of Pb (II) at equilibrium, T (K) indicates temperature, R (8.314 J mol^{-1} K^{-1}) is gas constant and K_d is equilibrium constant.

The positive value of ΔH^o for Si-ZnO NC (40.263 KJ mol^{-1}) assumes endothermic process of removal (Table 3). The spontaneity and feasibility of adsorption for Pb (II) were expressed by negative value of ΔG^o. Moreover, the positive value of ΔS^o (146.25 $Jmol^{-1}$ K^{-1}) validates the rise in extent of movement at solid - liquid interface at time of adsorption, which would increase the affinity of Si-ZnO NC for Pb (II) [27,28].

Table 3: Thermodynamic variables

T (°C)	ΔG^o (KJ mol^{-1})	ΔH^o (KJ mol^{-1})	ΔS^o (J mol^{-1} K^{-1})
15	-1.5668		
25	-3.5639		
35	-5.2648	40.263	146.25
45	-5.8119		

3.13 Regeneration and reusability

Adsorbent regeneration is a key parameter in treatment and removal processes. This study was performed up to three passes utilizing 0.1 M NaOH solution as desorbing reagent and data was plotted in Fig 7. Results make it quite evident that Pb (II) removal was exceeding 90% for first two cycles of reuse after which, it slightly reduced to 86%. Therefore, it can be stated that Si-ZnO NC has a minimum three cycle reuse limit when it comes to eliminating heavy metals.

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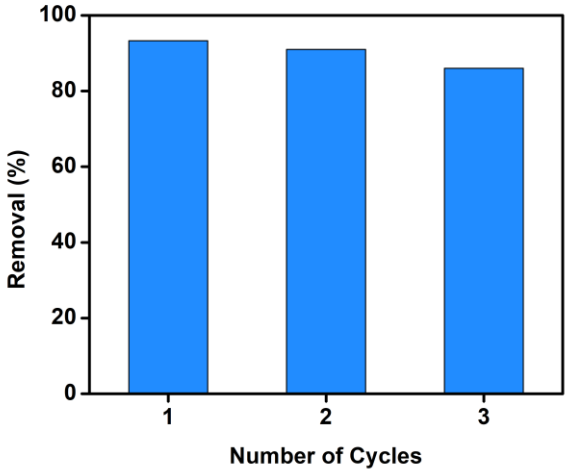


Fig 7: Reusability potential of biofabricated Si-ZnO NC for Pb (II)

4. Conclusions

In this work, Si-ZnO NC, a novel and environmentally acceptable adsorbent was fabricated and employed for removing Pb^{2+} ions from simulated wastewater. FTIR, XRD, SEM-EDX and BET analyzers were used for description and identification of adsorbent. The removal effectiveness of Si-ZnO NC for Pb^{2+} ions was found to be 94.6% at pH 6.5, equilibrium time 60 min, and adsorbent dose 0.5g/L. A stronger correlation coefficient (R^2 = 0.999) suggested that PSO model described the adsorption reaction's kinetics. The isothermal findings show that because of greater correlation coefficient (R^2 = 0.9959), adsorption reaction corresponds to Langmuir isotherm. Thermodynamic variables such as enthalpy change (ΔH^0), free energy change (ΔG^0), and entropy change (ΔS^0) were computed and results revealed that sorption process is spontaneous and endothermic. Regeneration and reusability test was performed by making use of 0.1 M NaOH as desorbing reagent and outcomes of study disclosed that removal effectiveness for Pb^{2+} exceeded 90% for two passes before declining to 86%. It is noteworthy to remark that the Si-ZnO NC has a minimum of three cycles of reuse when it comes to removing heavy metals from wastewater.

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RNN and LSTM-based model for predicting power demand

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Abstract

Forecasting power demand is essential in the electric industry as it provides the foundation for making decisions in power system planning and operation. Electrical companies employ a wide range of methods to predict power demands, spanning short-term, medium-term, and long-term forecasting. This paper aims to analyze all the factors contributing to the requested change and identify the root causes. It examines how artificial intelligence (AI) can improve the accuracy of energy demand prediction. AI enables us to model and understand highly complex systems, empowering companies to address the intricacies of power demand in ways previously unattainable.

Keywords: Electricity Forecasting, RNN, LSTM, Electrical Power, Consumption of Energy

Introduction

The electric power framework essentially includes an age, transmission, conveyance, and usage framework. To guarantee the effective exhibition of the Power Framework, an exceptionally fundamental and essential helper prerequisite of this large number of units is the activity and upkeep unit. The significant activity and support cost is in the creation area, trailed by the one for the appropriation area. By and by the monetary significance of the dispersion framework is extremely high and how much speculation included requests broad preparation, plan, development, and activity. Coordinating electrical energy utilization with the right degree of supply is essential since the abundance of power provided can't be put away, except if changed over completely to different structures, which causes extra expenses and assets. Simultaneously, misjudging energy utilization could be lethal, with an overabundance request overburdening the inventory line and in any event, causing power outages. There are substantial advantages in intently observing the energy utilization of structures ─ be they office, business, or family. With the coming of AI, precisely anticipating future energy utilization turns out to be progressively conceivable. Exact expectations give two overlapping benefits: first, supervisors gain key experiences in factors influencing their structure's energy interest, giving chances to address them and further develop energy productivity. Moreover, there can be surprising floods and drops in energy utilization because of hardware disappointment, supply disappointment, or just irregular vacillations that are challenging to make sense of. All the more explicitly, the goal is to accomplish more exact figures for the interest of power. Due to prescient examination, we can anticipate the upcoming electric interest with exceptional victories. Hence, this will be a critical development for organizations in the energy area. The utilization of AI implies better data to

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conclude what the best game plan is. Consequently, organizations that utilize this innovation will enjoy a serious upper hand over their rivals.

Related Work

Electricity is the turn in maintaining profoundly mechanically progressed industrialization in each economy. Pretty much every action done in this advanced period relies on power. The interest and utilization of electric energy[18] increment universally as the years pass, but the most common way of creating, communicating, and conveying electrical energy stays convoluted and exorbitant. A literature review based on electricity is defined in Table 1.

Table 1 literature review

Salah bouktif et al., Energies,2018	The author constructed and upgraded an LSTM-RNN-based univariate model for Demand side load prediction, which was determined precisely over both present moment and medium-term time horizons.[1]
Johannesen et al., Journal of Cleaner production,2019	The author performed different AI procedures like regression tools, random forest regressor, k-nearest neighbor regressor, and linear regression for examining metropolitan electrical energy request forecasting.[2,17,21]
Jordehi et al., Science Direct, 2019	That's what the author centered, request reaction programs have ended up being productive in the alleviation of many power framework challenges, for example, high age cost during top interest hours, unwavering quality issues, and blockage in age, transmission, and appropriation frameworks. To accomplish maximum capacity, DR programs should be executed optimally.[3]
Wen et al., Science Direct, 2020	The author proposed a model to estimate the load interest of private structures over a short to medium period. The proposed model can consolidate time conditions in the load information and accomplish a higher gauging precision when contrasted with the other method.[4,16]
Tan et al., Journal of Cleaner Production, 2019	The author built a consolidated determining model of power, intensity, cooling, and gas loads with the assistance of weight-sharing components in performing various tasks learning hypothesis and least squares support vector machine calculation, and the information from a Suzhou modern park was chosen for a case study.[5]
Ertugrul et al., Science Direct 2015	The author applied another variant of ELM[20] to prepare a single secret layer repetitive brain network to accomplish higher estimating power load accuracy.[6]
Lau et al., Science Direct 2019	The author presents a general perspective on the information combination procedures tracked down in smart city applications. The creator proposes a viewpoint characterization for the brilliant city application that includes information combination techniques.[7]
E. O'Dwyer et al., Science Direct, 2019	The author studies the ongoing bearings in smart energy frameworks for brilliant urban communities and attracts on our understanding fostering an enormous scope EU pilot project for constant execution of the same.[8]
A.Eseye et al., IEEE, 2019	The author proposed and executed a BGA-based highlight determination approach for further developed momentary power request estimating models.[9]
J. bedi et al. , Elsevier , 2019	In this, the author introduced a structure to estimate power interest. The methodology frames its premise on a lengthy momentary memory network moving window-based strategy and can be utilized to assess interest for the time stretch indicated by the user.[10]
P.jiang et al., Elsevier, 2020	In this paper, the author proposed a composite idea for power request determination. It principally coordinates VMD procedure, FFT strategy, and SVR-based smart advancement calculation. [11]

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Background

Man-caused intellectual prowess and simulated intelligence computations have dynamically transformed into a fundamental piece of a couple of organizations. As of now, they are progressing toward splendid city drives, expecting to modernize and advance metropolitan activities and exercises at large. Computer-based intelligence is used everywhere from automating ordinary endeavors to offering cunning encounters, and adventures in every space endeavor to benefit from it. The goal of simulated intelligence generally is to understand the development of data and fit that data into models that can be seen and utilized by people. A machine can sort out some way to deal with an issue by following any of the going with three systems.

These are the manners by which a machine can learn:

1. Supervised Learning
2. Unsupervised Learning
3. Reinforcement Learning

Supervised Learning

Supervised learning is a procedure wherein we educate or prepare the machine utilizing information that is very much marked.

Unsupervised Learning

Unsupervised learning includes preparing by utilizing unlabeled information and permitting the model to follow up on that data without direction.

Reinforcement Learning

Reinforcement Learning is a piece of AI where a specialist is placed in a climate and he figures out how to act in this climate by playing out specific activities and noticing the prizes he gets from those activities.

DEEP LEARNING

Deep learning is a piece of computer-based intelligence that is completely established on fake mind associations, as mind organization will reflect the human frontal cortex so significant learning is moreover a kind of duplicate of the human psyche. Deep learning is a particular kind of man-made intelligence that achieves exceptional power and versatility by sorting out some way to address the world as a settled food chain of thoughts, with each thought described similarly to simpler thoughts, and more calculated depictions enrolled in regards to less unique ones.

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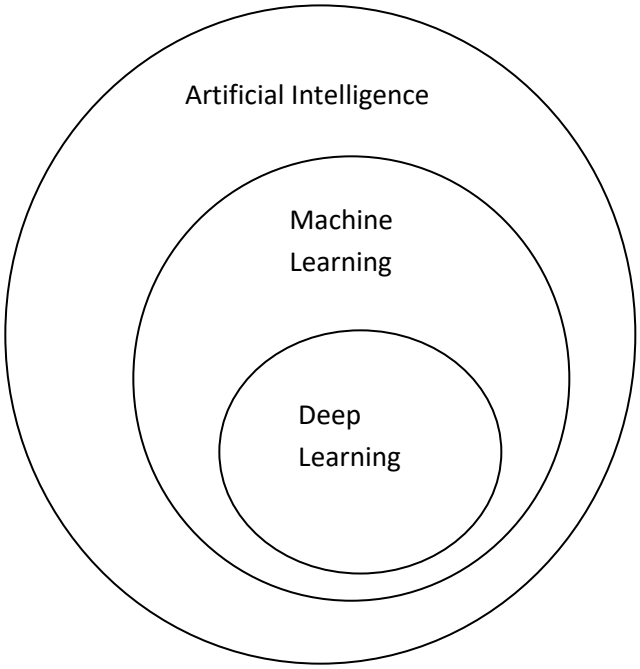


Figure 1 Architecture of techniques

Deep learning is a particular subset of AI, which is a particular subset of Man-made consciousness as displayed in Figure 1. For individual definitions:

- Artificial Intelligence is the wide command of making machines that can think intelligently.
- AI is one approach to doing that, by utilizing calculations to gather bits of knowledge from information.
- Deep Learning is one approach to doing that, utilizing a particular calculation called a Neural Network.

TECHNIQUES USED

We used a Recurrent Neural Network (RNN) which is a class of fake mind networks where the relationship between centers structures an organized outline along a common progression. This allows it to show a common novel approach to acting. LSTM networks are suitable for requesting, taking care of, and making assumptions considering time series data, since there can be slacks of dark length between huge events in a period series. LSTMs were made to deal with the dissipating point issue that can be capable while getting ready standard RNNs. Even more unequivocally, the objective is to achieve more accurate guesses for the interest in power. Because of perceptive assessment, we can anticipate the forthcoming electric interest with incredible triumphs. Subsequently, this will be a gigantic improvement for associations in the energy region.

Recurrent Neural Networks

RNNs are significant solid areas for a decent sort of brain affiliation and have a spot with the most inspiring assessments being used considering how it is the only one with an inside memory.

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Comparatively, to other huge learning calculations, repetitive psyche networks are overall old. They were at first made during the 1980s, yet of late have seen their veritable potential. An augmentation in computational power near the enormous extents of information that we now need to work with, and the headway of long transient memory (LSTM) during the 1990s, has truly passed RNNs on to the extreme front. On account of their internal memory, RNN as shown in Figure 2 can recollect basic things about the information they got, which licenses them to be particularly cautious in guessing what's coming right away. Along these lines, they incline in the direction of calculation for moderate information like time series, talk, text, monetary information, sound, video, climate, and altogether more. Sporadic brain affiliations can move toward a lot of further discernment of a social event and its setting stood apart from different calculations. To get a handle on RNNs appropriately, you'll require working information on "ordinary" feed-forward mind affiliations and progressive information. Successive information is referenced information in which related things follow one another. Models are cash-related information or DNA gathering. The most outstanding kind of moderate information is maybe time series information, which is only a development of server farms that are kept in time interest.

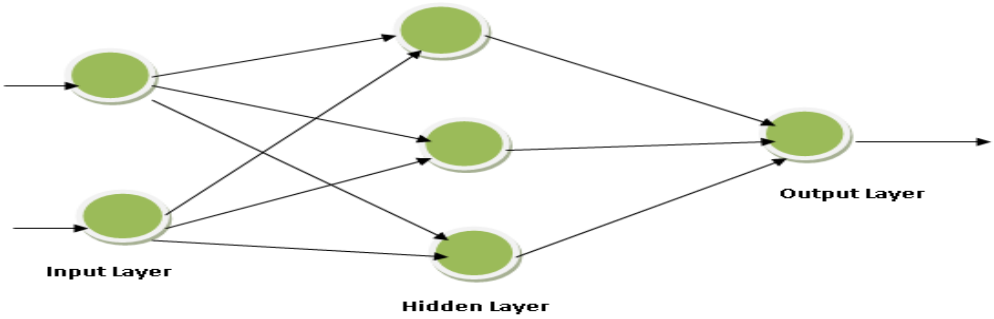


Figure 2. 3-Layer RNN Network

Feed-forward network includes 3 layers: the info layer, the stowed-away layer, and the outcome layer. In a feed-forward frontal cortex affiliation, the data just moves in a singular bearing from the information layer, through the secret layers, to the result layer. The data moves straight through the affiliation and never contacts a middle two times. Feed-forward frontal cortex networks have no memory of the information they get and are dreadful at guessing what's coming right away. Since a feed-forward network just considers consistent information, it knows nothing about requests in time. It on a very basic level can't remember anything about what occurred in the past except its status.

In a RNN the data pushes through a circle. Right when it pursues a choice, it considers the nonstop data and what it has gained from the data sources it stretched out beyond time. A standard RNN has a transient memory. In blended in with an LSTM as displayed in Figure 3, they have a long memory.

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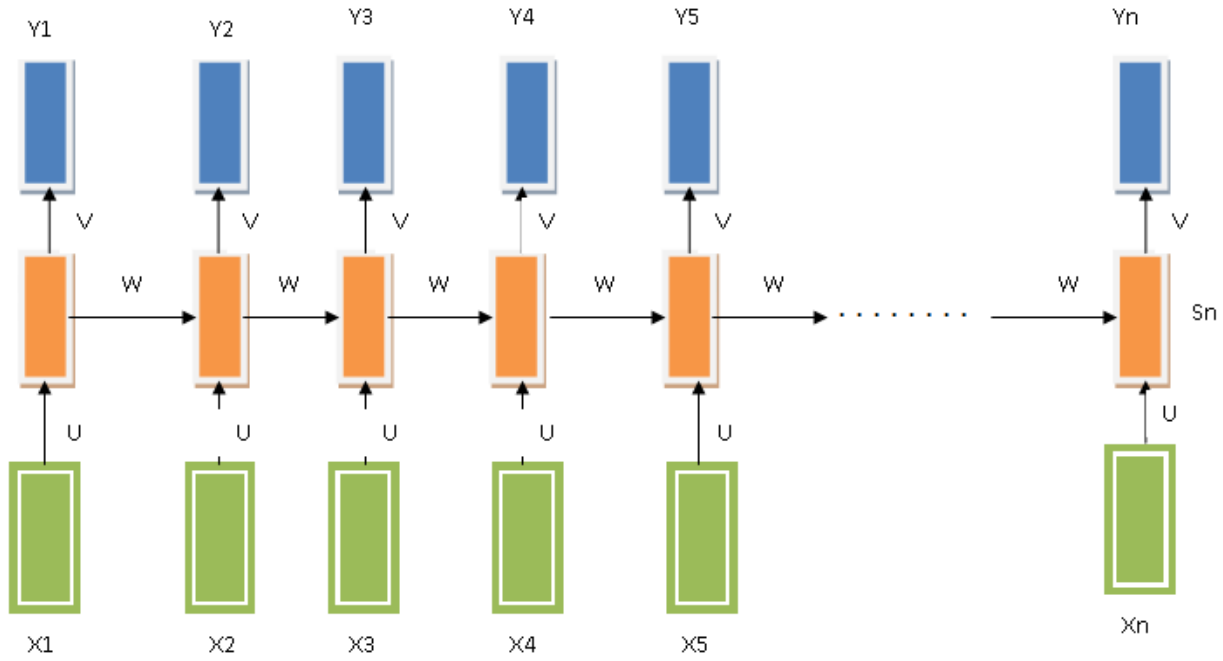


Figure 3 LSTM Model

A recurrent neural network, nevertheless, can remember those characters because of its internal memory. It produces yield, copies that outcome, and circles it back into the association. Thus, an RNN has two wellsprings of data: the present and the new past. This is critical considering the way that the gathering of data contains imperative information about the thing that is coming immediately, which is the explanation an RNN can do things various estimations can't.

Could we see how the above structure be used to expect the fifth letter in "h"? In the above structure, the Middle RNN block (i.e., hidden away layer of RNN) applies something many allude to as a recurrent recipe to the data vector and besides its previous state. For this present circumstance, the letter "h" has nothing going before it, we ought to acknowledge the letter "e". So at the time the letter "e" is given to the association, a recurrent recipe is applied unequivocally "e" and the previous state which is the letter "h". These are known as various time steps of the data. So if at the time I, the data is "e", at time I-1, the data was "h". The recurrent recipe is applied to e and h both and we get another state.

A formula that is applied to get the Hidden layer of RNN is:

$S_i = \sigma(Ux+WS_{i-1}+b)$

A formula that is applied to get the final output of RNN is:

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$Y_i = O(VS_i+c)$

Here, Si is the condition of the organization at timestamp I. The boundaries are W, U, and V which are shared across time steps. However, Yi is the result layer capability which takes the qualities from stowed stowed-away layer and creates the result.

Two significant issues happen in RNN. An inclination is a fractional subordinate regarding its bits of feedback i.e., a slope estimates how much the result of a capability changes if you change the data sources a tad. You can likewise consider an inclination the slant of a capability. The higher the inclination, the more extreme the slant and the quicker a model can learn. Be that as it may, assuming the slant is zero, the model quits learning. A slope essentially gauges the adjustment of all loads as to the adjustment of mistake. To keep away from this issue LSTM is utilized to expand the abilities of RNN.

Long short-term memory (LSTM)

Long short-term memory networks are an expansion for intermittent brain organizations, which fundamentally expands memory. Along these lines, it is appropriate to gain from significant encounters that have extremely prolonged periods in the middle between. This dealt with the issue of long-haul reliance of RNNs where RNNs can't recuperate the term set aside in long-haul memory yet can give additional definite assessments from late information. RNN doesn't give strong execution as the range length increases. LSTM can hold information for a long time normally. It is used for getting ready, estimating, and gathering reliant upon time course of action data in Figure 4.

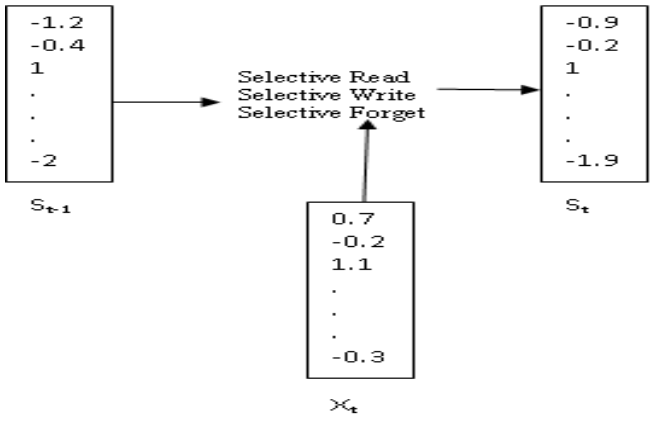


Figure 4 An Example Scenario of LSTM

We have processed a state St-1 at timestamp t-1 and presently we need to over-burden it with new data Xt and register another state St. While doing we need to ensure that we utilize particular read, specific compose, and specific forget so just significant data is held in St as displayed in figure 1.

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Information is retained by the cells and the memory manipulations are done by the **gates.** There are three gates –

Selective write:-

The errand of removing helpful data from the ongoing cell state to be introduced as a result is finished by a particular composition as displayed in Figure 5

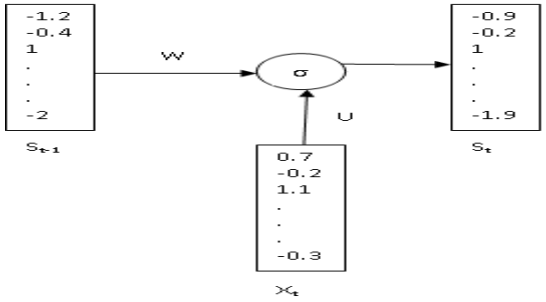


Figure 5 Example Scenario about selective writing in LSTM

Recall that in RNN we use s_{t-1} to compute s_t.

$S_t=\sigma(W*s_{t-1}+U*X_t)$ (ignoring bias) (1)

In any case, presently as opposed to passing St-1 for all intents and purposes to St, we need to pass just segments of it to the following state. For this, we present a vector Ot-1 which concludes what part of every component of St-1 ought to be passed to the following state.

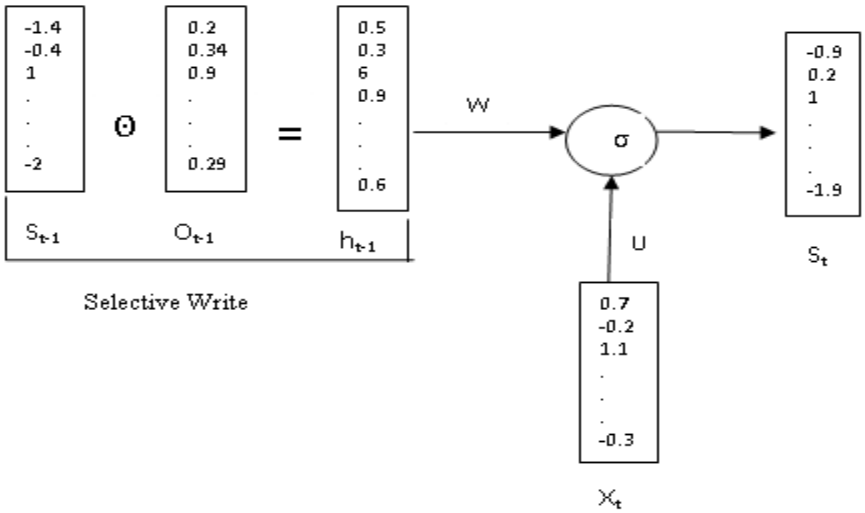


Figure 6 Example of selective writing in LSTM

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We present a vector Ot-1 which finishes up with which part of every part of St-1 should be passed to the accompanying state. Each part of Ot-1 gets expanded with the connected part of St-1. Each part of Ot-1 is restricted to someplace in the scope of 0 and 1. Regardless, how might we handle Ot-1? How does the RNN have in any event some thought of which part of the state to pass on? Well the RNN needs to learn Ot-1 alongside various limits (W, U, V). We process Ot-1 and ht-1 as shown in Figure 6:

$$O_{t-1}= \sigma(W_0*h_{t-2}+U_0*X_{t-1}+b_0) \quad (2)$$

$$h_{t-1} = O_{t-1} \Theta s_{t-1} \quad (3)$$

The limits W0, U0, and b0 ought to be progressed close by the ongoing limits W, U, and V. The sigmoid capacity ensures that the characteristics are between 0& 1. It is referred to as the subsequent entryway as it picks the sum to inhale a simple task.

Selective read:

After passing the appropriate information from the past doorway in conditions 1, 2, and 3, we present another mystery state vector Ŝt. Ŝt will as of now use ht-1 to deal with the new state at the accompanying time step as shown in Figure 7. We will moreover use Xt which is the new commitment at time step t.

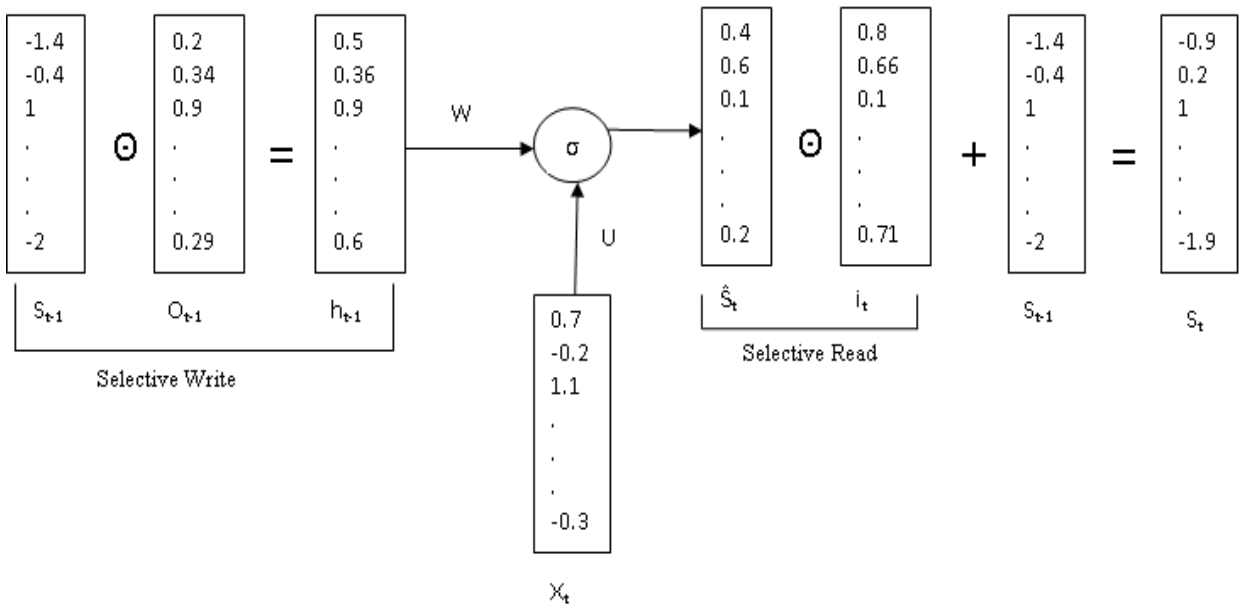


Figure 7 Example of selective read in LSTM

$$\hat{S}_t=\sigma(W*h_{t-1}+U*X_t+b) \quad (4)$$

Note that W, U, and b resemble the limits that we used in RNN. Ŝt consequently gets every one of the information from the past state ht-1and the current status Xt. In any case, we likely shouldn't use this new information and just explicitly examine it before building the new cell state St.

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To do this we present another entryway called the info door.

$$I_t=\sigma(W_i * h_{t-1}+U_i * X_t+b_i) \quad (5)$$

Furthermore, use It ʘ Ŝ as the specifically perused state data.

Selective forget:

After specifically perusing and composing the data, presently we intend to fail to remember all the insignificant stuff that could be useful to us to cut the messiness utilizing conditions 4 and 5.

How might we merge St-1 and Ŝ to get the new state? Here, is one direct way to deal with this:

$$S_t=S_{t-1}+I_t \text{ ʘ } \hat{S} \quad (6)$$

Yet, we may not utilize the entire of St but rather neglect a few pieces of it as displayed in Figure 8.

To do this we present the neglected entryway.

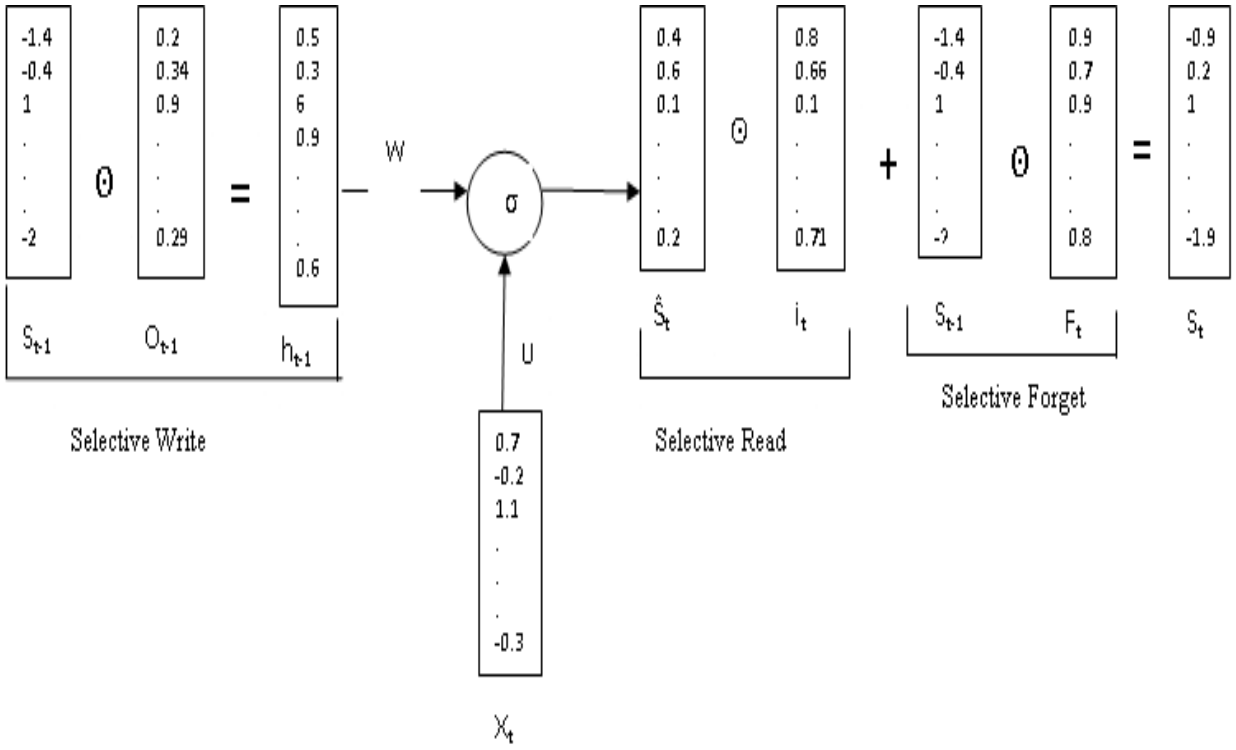


Figure 8 Example of Selective Forget in LSTM

$$F_t=(w_f * h_{t-1}+ U_f * X_t+b_f) \quad (7)$$

$$S_t=S_{t-1} \text{ ʘ } f_t + I_t \text{ ʘ } \hat{S} \quad (8)$$

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We presently have the full arrangement of conditions for LSTM from conditions 1 to 8.

ARCHITECTURE

The model for predicting the electricity demand is shown in the figure. The model for prediction consists of the following steps mainly dataset preprocessing data cleaning, and feature selection after that dataset is grouped based on the days and holidaywise because the electricity demand is different based on the days. The electricity demand that is required on Monday is different from the demand that is required on Sundays and Saturdays(I.e., Weekends). So, clustering of data is a necessary step for better prediction of electricity prediction. After the dataset is divided into clusters prediction technique will be applied for predicting the electricity demand. Before model preparation and testing, the crude information will first be investigated and pre-handled to decrease the intricacy of the model preparation and to deal with any missing information. At long last, each model will be assessed involving approval measurements as displayed in stream graph 9.

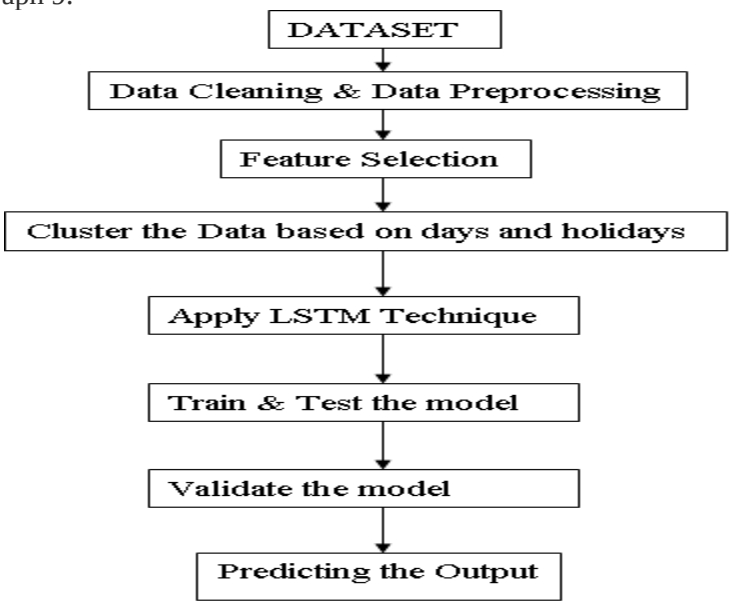


Figure 9 Flow chart for Electricity demand prediction

Data Set and Dataset preprocessing

We have a Total number of years: 15 Say, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018. The energy consumption in megawatts is plotted on the Y-axis of the graph and the number of years is plotted on the X-axis of the graph. Now our Idea is to refine this huge data into mean values of each day and perform the RNN model to train this data set for accurately predicting the Energy of the last 2 months. The Old Dataset had shape as (121273, 7) and after taking the mean of each day we have a New Dataset of shape (5055, 4). AI grants us to show and see extremely complex frameworks that permit organizations to address the intricacy of power interest in a manner previously unattainable. Also, the trend of Energy Consumption According to Year is plotted in Figure 10:

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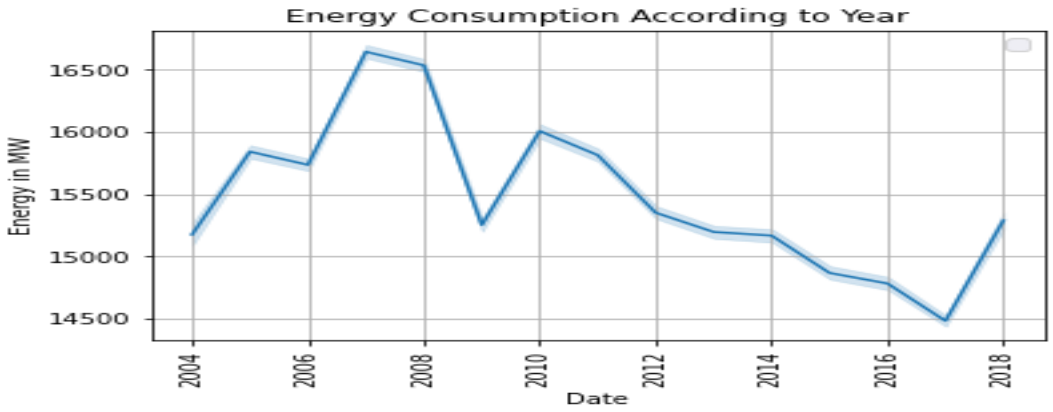


Figure 10 Energy Consumption graph

Now, to visualize the data we plotted this plot of Energy in Mega Watts and density. Initially, the data was of shape: (121273, 7) and after taking the mean of each day we created this new data set of shape (5055, 4). Now working on this data set is quite easy to perform. Out of which we separated 100 end values as Test Data to later compare that with the one we are going to predict.

Training and testing of Model:

The model was made to work with 4 layers of LSTM each layer dropping out 20% sequences. In the end, we added one output layer. And after compiling the RNN model using ADAM Optimizer and loss calculated as MSE we got the machine trained by 50 epochs. The greater the epochs the more precise the model will work. It took almost 30 minutes to train the model.

But the output is beautiful to witness. The test data was made to reshape and then normalized to get the final values.

Validate the Model:

We used a metric to evaluate our model: Mean Squared Error (MSE)

Its expression is:

Mean Squared Error = $Minimize(\frac{1}{N}[\sum(\hat{Y} - Y)^2])$

Likewise, we utilized MSE Misfortune to improve our RNN. The strength of MSE is that it rebuffs bigger mistakes because of its squared nature, lessening our model's probability of making outrageous expectations which would be expensive or even hazardous. Negligibly, our model should accomplish lower MSE than constancy, an insignificant benchmark gauge where the "anticipated future worth 1 day ahead = noticed present worth". Constancy is a decent benchmark to begin with due to the exceptionally occasional nature of energy utilization. The mean squared mistake for the expectation of power request estimating utilizing LSTM and RNN is 9.4%.

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Predicting Output:

We were lucky to see how accurately and precisely we were successful in predicting the values and the trend says it all how near the values of the actual data set and predicted data set are. The model worked and we were successfully able to predict the next 2 months' energy demand of the firm whose data set was taken from Kaggle.

RESULTS

We involved pandas in getting the informational index. Matplotlib and seaborn are the libraries for Information Representation. Tensorflows as displayed in Figure 11 is one of the more well-known libraries to carry out the Profound Brain Organizations. Keras which is an open-source programming library that gives a Python point of connection to counterfeit mind associations. Keras goes probably as a place of connection for the TensorFlow library. The Model preparation was performed and the computer processor required very nearly 30 minutes playing out the underneath-introduced activity. It went without a hitch and the outcomes are lovely to observe. We made 50 ages more prominent the quantity of Ages the more prominent the exactness of expectation.

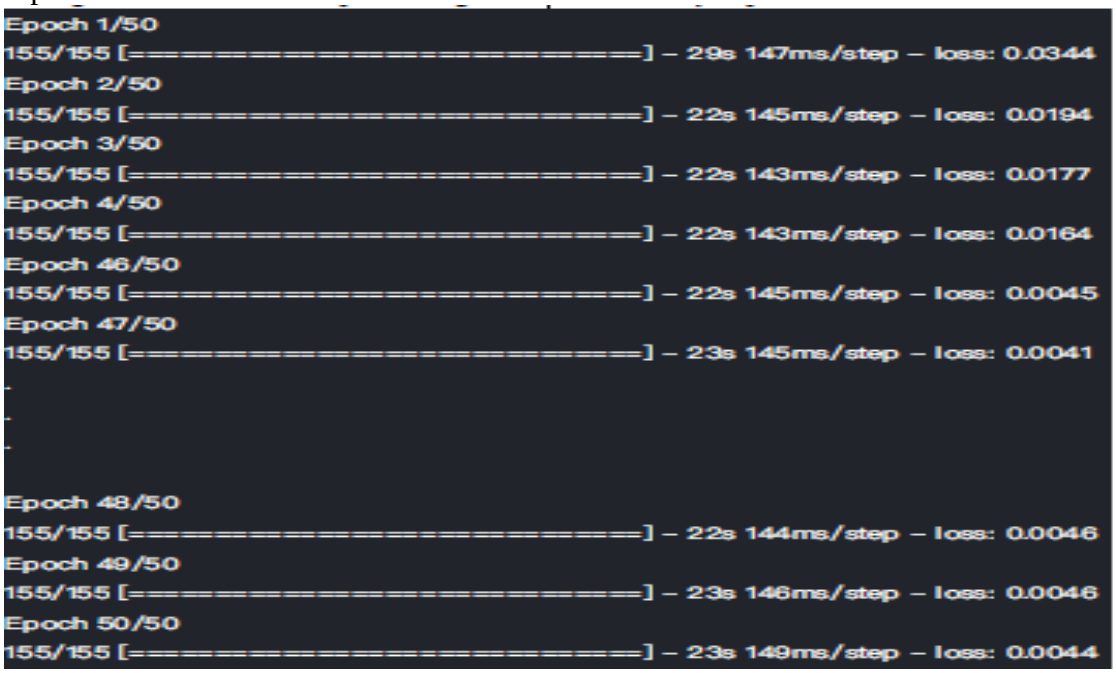


Figure 11 Data Visualization using Tensorflow

Now we made the required actions to perform on the trained data and concatenated the column of prediction with true values to compare the values as shown in table 1.

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	Date	TrueMegaWatt	PredictedMegaWatt
0	2018-04-26	13157.791667	13528.794922
1	2018-04-27	12964.000000	13357.995117
2	2018-04-28	12237.583333	14388.614258
3	2018-04-29	12156.791667	13113.623047
4	2018-04-30	13443.500000	12920.691406
...	...	...	...
95	2018-07-30	15368.083333	15151.763672
96	2018-07-31	15180.291667	15479.292969
97	2018-08-01	15151.166667	15083.296875
98	2018-08-02	15687.666667	15261.788086
99	2018-08-03	14809.000000	15270.975586

100 rows × 3 columns

Table 1 Comparing True values with predicted values.

This table clearly shows how precisely the predicted values were to the Actual values in Mega Watts. At last, we plotted this Graph of True Values and Predicted Values on a 2D plot as shown in Figure 12 of Power in MW on the y-axis and Dates on the x-axis. The machine was successful in learning the pattern of Energy Consumption as we can see in the below graph.

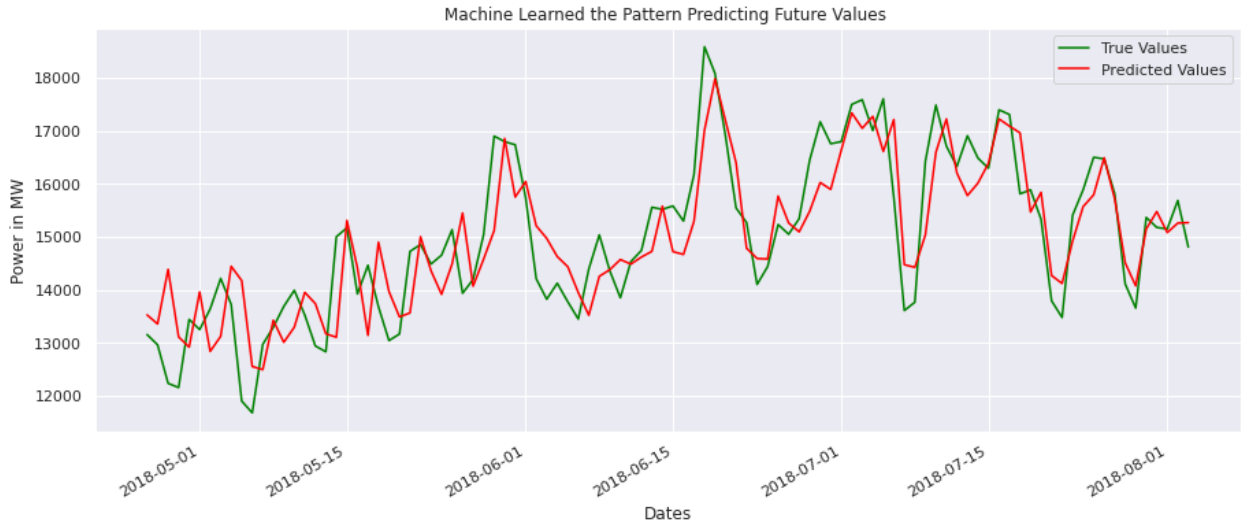


Figure 12 Time series Prediction of actual and predicted values

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From 2018-05-01 to 2018-08-01 the trend is plotted. The red line is for predicted values and the green line is for True values.

CONCLUSION

Basic, measurable strategies and artificial intelligence for information analysis were developed some time ago. However, the use of advanced techniques for intelligent data analysis has become increasingly relevant in recent times. Data mining considered a new generation of information processing technology, plays a crucial role in extracting insights from data. In general, regarding the overall evolution of modern and business power consumption, direct power trading is expected to account for 70% to 90% of total power consumption in the future. Accurate forecasts can assist managers in understanding the volume and trends of future energy consumption, allowing for better scheduling and planning of supply system operations.

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ENHANCING ROAD SAFETY THROUGH COMPUTER VISION: SEATBELT AND HELMET DETECTION USING CANNY EDGE DETECTION AND HOUGH LINE TRANSFORM

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Abstract

Wearing seatbelts and helmets significantly reduces extreme affliction exposure in accidents, studies show up to 45% mitigation in lethal injuries with seatbelts and a 69% reduction in head injuries with helmets. This research exploits advanced computer vision techniques—Canny Edge Detection and Hough Line Transform—to augment seatbelt and helmet detection precision. Canny Edge Detection secures accuracy through edge conservation and noise diminution. Hough Line Transform algorithm outshines in locating straight lines associated to imperative safety equipments. Its inventiveness not only renders adaptable real-time remedy but also amplifies road safety by accurately detecting seatbelt and helmet use, reducing latent risks productively.

Keywords

Road Safety, Computer Vision, Seatbelt Detection, Helmet Detection, Canny Edge Detection, Hough Line Transform, Image Processing.

1. Introduction

In the everlasting quest of road safety, the combination of high-tech technology appears as a promising indicator. Worldwide road accidents persist as an impressive challenge, exacting inventive tactics to alleviate their effect. Numerous of these incidents initiate from the overlook of foundational safety pr**otoco**ls, such as seatbelt and helmet utilization. While traditional implementation methods are elementary, they struggle with persistent adherence payable to fundamental human restrictions. This exploration scrutinizes into the confluence of computer vision and transportation safety, concentrating typically on identifying seatbelt and helmet utilization. In an era where roads incorporate both advancement and hidden menaces, the mandate to improve safety protocols is foremost. Traditional approaches, though pivotal, are limited by individual constraints and fall short in confirming standard compliance to safety guidelines.

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Engage in the discipline of automated vision, where techniques and pixels concentrate to develop intelligent systems able of understanding visual statistics. The exposure here is on exploiting the competencies of Canny Edge Detection and Hough Line Transform techniques to acknowledge and monitor seatbelt and helmet use. This integration of elegant image crafting techniques with necessary road safety methods unveils channels for autonomous, real-time surveillance framework modification in the conventional implementation surroundings. As we maneuver roads filled with obstructions, the influx of computer vision algorithms promises a revolutionary method to improve safety, surpassing the boundaries of conventional approaches.

1.1 Challenge and Practical Applicability:

The limitation goes beyond the technical complexities of these techniques to their effortless integration into our daily lives. The crux of this study surpasses mere precision in identification, highlighting its practical importance. It sets the foundation for intelligent transportation systems, preventively improving safety. Traversing through this research, the goal is to surpass conventional security borders, imagining a future where observance is not just expected but simply organized and protected through the careful monitoring of computer vision. The passage initiates with the recognition that roads can be safer, and the intersection of technology with safety protocols aids as the leading scope toward that contemplated destination. This quest aims to reformulate safety protocols, proclaiming an era where technology becomes a natural associate in confirming our safety on the roads.

1.2 The Significance of Automated Detection:

Against this context, the research at hand pursues to investigate the skills of computer vision algorithms, specifically Canny Edge Detection and Hough Line Transform, in optimizing the identification and inspecting of seatbelt and helmet usage. The objective is to escort a paradigm shift by enabling real-time, autonomous surveillance that enhances the margins of manual measures.

1.3 Research Question and Hypotheses:

This study is driven by the comprehensive question of whether computer vision can effectively boost road safety through the usage of automated detection of seatbelts and helmets. The hypothesis postulates that the merging of these algorithms will provide accurate and efficient detection. By providing this concise yet comprehensive introduction, this paper aims to integrate the research, underscore its importance in the area of road safety, and put the preliminary work for an in-depth scrutiny of the approaches and findings.

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2. Literature survey

On a Global scale, road traffic accidents, accountable for 1.35 million yearly deaths and a vital cause of fatality among 15-29-year-olds, also impose long-term disabilities on 20-50 million survivors, according to the World Health Organization. The magnitude of influence underscores the imperative need for effective deterrent strategies. Table 1 presents an extensive survey of seatbelt and helmet detection systems, highlighting Methodologies and Key Findings.

Table 1: Surveys on Seatbelt and helmet Detection Problem

Survey	Objective	Sample Size	Methodology	Key Findings
1. "Road Safety Survey" by the World Health Organization	To determine the dominance of seatbelt and helmet use between road users	12,500 road users in 10 countries	Face-to-face interviews and observation	Only 63% of drivers and front-seat passengers put on seatbelts, while only 50% of motorcycle riders had on helmets
2. "Helmet Use Among Motorcyclists in the United States" by the National Highway Traffic Safety Administration	To evaluate the pervasiveness of helmet use among motorcyclists in the United States	4,749 motorcyclists in 5 states	Observational study	Only 50% of motorcyclists sported helmets, with the highest usage rates in states with universal helmet laws
3. "Factors Affecting Seat Belt Usage in Passenger Vehicles" by the National Highway Traffic Safety Administration	To identify factors that influence seatbelt use between drivers and passengers in the United States	12,000 drivers and passengers in 12 states	Phone surveys and observational study	Younger drivers and passengers, males, and rural residents were less likely worn seatbelts
4. "Helmet Use Among Bicyclists and Associated Factors in a Bicycle-Friendly City in China" by BMC Public Health	To examine helmet use surrounded by bicyclists in a Chinese city	2,532 bicyclists	Observational study	Only 16.3% of bicyclists had on helmets, with the highest usage rates among those who perceived cycling as dangerous and those who owned a helmet
5. "Seat Belt and Mobile Phone Use Among Drivers in Kuwait: Prevalence and Associated Factors" by the Journal of Injury and Violence Research	To analysis seatbelt and mobile phone use between drivers in Kuwait	1,002 drivers	Face-to-face interviews and observational study	Only 45.5% of drivers had on seatbelts, and 83.6% used mobile phones while driving

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In the domain of seat belt and helmet detection, previous research endeavors have explored distinctive approach and algorithms. In the paper titled "Smart Video Analytics System" proposes a system incorporating computer vision, prioritizing seat belt detection and automated number plate recognition. The Canny edge detection algorithm was used to detect the edges and Hough line transform algorithm is used to detect the seatbelts in the images. But the system was not been able to detect the seatbelt in case of if colors of clothes same as the color of the seatbelt and various enlightening conditions.

In the paper titled "Helmet Detection using Machine Learning and Automatic License Plate Recognition" utilizes the YOLOv3 model for real-time helmet detection, paired with OCR for license plate recognition. Conquering previous flaws, the YOLOv3 model demonstrates high precision, exhibiting its potential in real-time accomplishment through webcams or mobile cameras.

In the arena of vehicle safety, the paper "Vehicle Safety Belt Detection & Plate Number Recognition using Machine Learning" proposes an algorithm harnessing Hough Transform for seat belt detection and ANPR for license plate identification. Focusing on the importance of seat belt usage, the study aims to streamline detection for augmented road safety and traffic management.

The "Global Status Report on Road Safety" by WHO provides an extensive overview, emphasizing the global relevance of road safety. Serving as a guideline, the report endorses for vigorous safety precautions to mitigate the alarming rates of traffic-related casualties and injuries worldwide.

3. Proposed work

Within this section, we unveil the systematic tapestry instrumental in constructing a robust seatbelt and helmet detection system. Our research method coordinates the ensemble of data collection, algorithmic integration, metrics for evaluation, and the formation of experimental protocols. The proposed architecture is shown in Fig.1.

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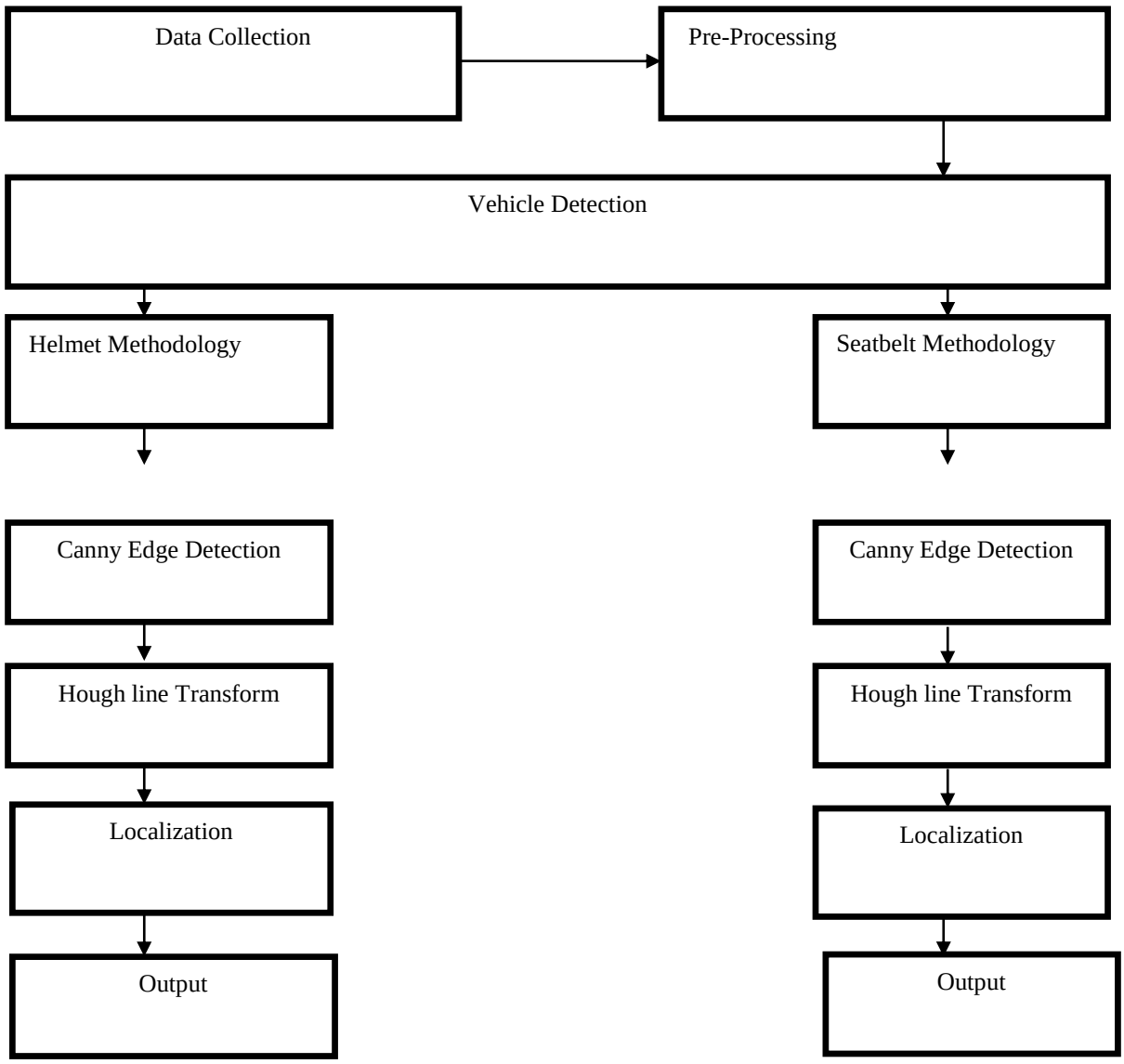


Fig.1 Architecture of proposed system

1. Data collection

The dataset applied in this study was diligently assembled to ensure a extensive representation of real-world circumstances. Images were acquired from various catalogs, including Kaggle, Pexels, Google Images, Images.cv, and Roboflow Universe. The assorted provenances of the datasets were chosen to incorporate a diverse range of surroundings, lighting conditions, and image qualities.

2. Pre-Processing

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The preliminary segment substantially enhances the proposed infrastructure durability and efficiency by highlighting essential characteristics and minimizing noise, thereby smoothing the route for accurate seatbelt and vehicle identification outputs. This basic segment implements a sequence of diligently employed algorithms, managed antecedent to evaluation. This incorporates rescaling pictures for normalization, transforming them to grayscale for rationalizes executing, and applying blurring techniques for noise mitigation and improved smoothness. Consequently, the deployment of the Canny Edge detection technique determines edges, whereas the Hough Line Transformation characteristics extraction technique depicts and detects direct lines within the seatbelt and helmet zone.

3. Helmet Methodology

In the helmet identification method, preliminative segment include the determination of two-wheelers using Canny edge identification, succeeded by the extraction of the region of interest (ROI). Upon delineating the two-wheeler zone, a Haar Cascades-based face identification approach is applied to identify the existence of a rider. Consequently, the model evaluates whether or not the rider is putting on a helmet. A positive statement is formed if a helmet is identified; otherwise, a negative outcome indicates the non existence of a helmet.

4. Seatbelt Methodology

In the seatbelt identification process, the system applies the Canny Edge detection algorithm to uncover the edges of the seatbelt within the rendered picture. This algorithm improves the specification of substantial contours by identifying immediate changes in severity, thereby highlighting the constraints of the seatbelt. Consequently, we apply an attribute retrieval technique, specifically the Hough Line Transformation, to represent and discern direct lines linked with the seatbelt sphere. This process outperforms in displaying lines within the picture domain, supporting the recognition and formulation of the seatbelt architecture built on its individual straight characteristics.

5. *Algorithm*

5.1Canny edge Algorithm

The Canny Edge identification approach, formulated by John F. Canny in 1986, performs as an image handling approach focused at recognizing borders within an image. Its pervasive implementation for edge identification emerges from its expertise at perceptive considerable changes in Potency. The approach include serial steps: Grayscale Conversion, Gaussian Smoothing, Gradient Calculation, Non-Maximum Suppression, and Edge Tracking by Hysteresis, cumulatively collaborate to its potency in emphasizing and obtaining boundaries accurately.

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5.2Hough line Transform

The Hough Line Transform represents as a fundamental approach within computer vision and image scrutiny, focusing in the recognition of straightforward lines among visual representation. Its efficiency lies in discriminating lines, comprising edges, even when encountered with difficulties like noise and changes in light. This extensive method integrates fundamental factors such as Edge Identification, Parameter Space assessment, Voting mechanisms, Accumulator Array unification, Peak Detection approaches, and the subsequent Line Reconstruction steps.

6. Localization

Localization is obtained through an advanced image handling process alluded to as Thresholding. Within this technique, pixels in the picture encounter compression, applying one of two standards mandated by the detailed threshold. To identify the most favorable threshold esteem, a source review is performed. Boosting this method, a versatile thresholding approach implements a regional threshold utility for each visual element. This vibrant method proves essential in conquering hurdles affiliated with irregular lighting, verifying more specific and comprehensive localization results.

4. Experimental setup

The fundamental architecture as shown in Fig.2 incorporates intuitive data from both two-wheelers and four-wheelers for a comprehensive evaluation. Precisely managing two-wheelers, the system entrains in a specific surveillance, focusing on the recognition of helmets. The model assuredly portrays its outputs, confirming the existence of a helmet upon locating or displaying the scarcity of a identified helmet in cases of comprehensive examination. Adjusting its concentration to four-wheelers, the selective application precisely examines seatbelt state in pictures. The difficulty of determining if a person is attiring a seatbelt displays a substantive implementation challenge, given the belt's slight width, approaching productive identification. This elaborateness is compounded in occurrences where the belt color integrates with the person’s clothing, possibly deriving in distorting resultants. Precision in confirming seatbelt utilization requests a thoughtfully formulated technique. Leveraging on the capacities of neural networks and artificial intelligence, this technique clearly enhances correctness, efficiently measuring whether a person has strongly tied their seatbelt. This innovative approach secures a detailed analysis, adroitly handling obstacles connected with seatbelt detection in different circumstances.

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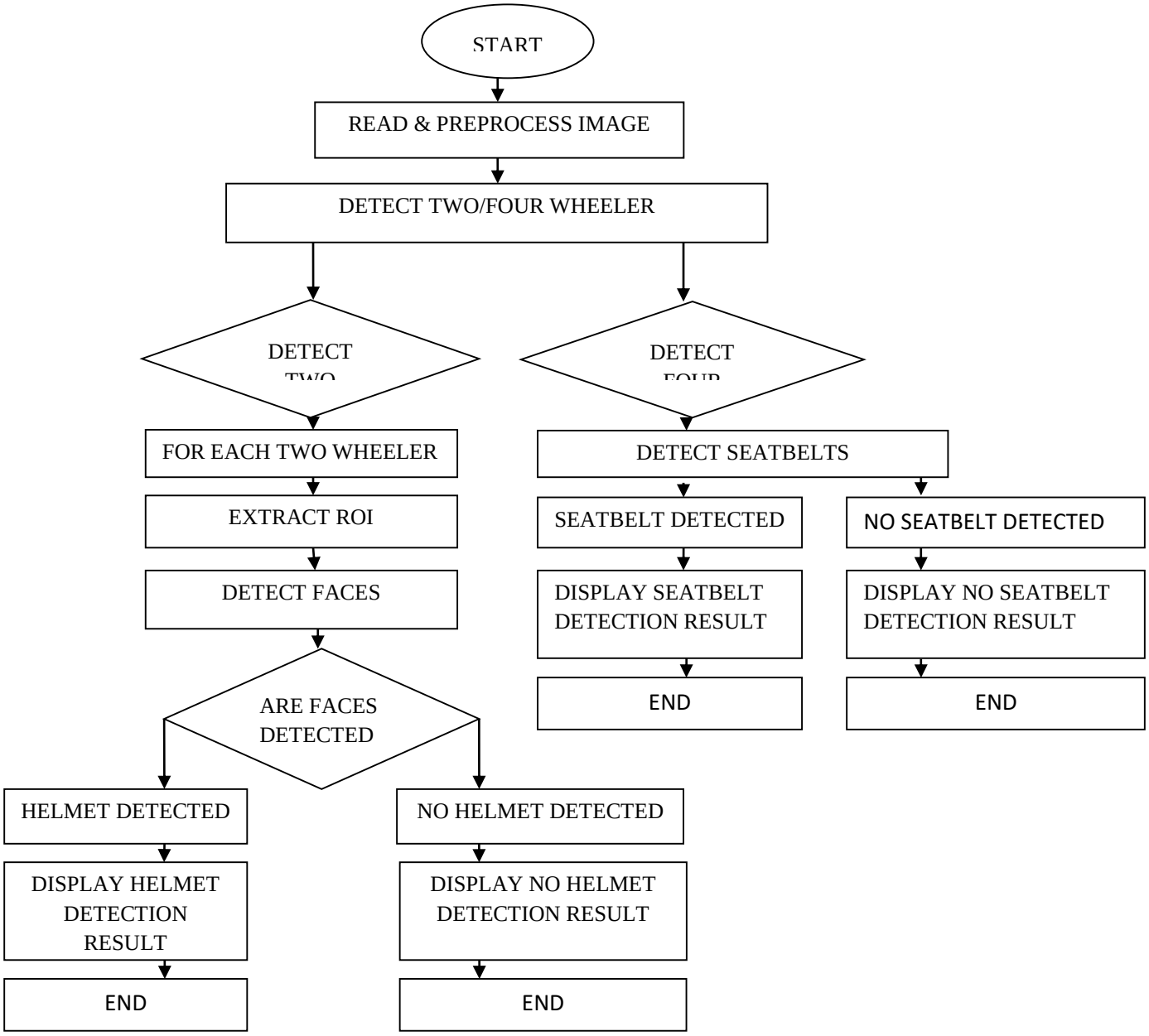


Fig.2 Flowchart of Proposed System

5. Results and discussion

In the domain of image analysis, specifically pivotal for visual consciousness practicalities, improving image functionality involves reducing data quantity while keeping fundamental details. A vital method for attaining optimum results incorporates exploiting the Hough Line Transformation algorithm on web-based images. This revolutionary method describes lines in

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either slope-intercept form (y = mx + b) or through mathematical expression using ρ and θ to adjust numerous line directions. This technique displays versatility, adaptable outcomes where lines transit upward or downward the root. The technique instigates by transforming four-wheeler vehicle depictions into grayscale, ensued by visual blur for refinement. Consequently, the Canny Edge Detection algorithm recognizes edges, and the Hough Line Probabilistic Transformation represents lines in the seatbelt zone, sustaining to seatbelt detection.

For four-wheeler automobiles, the method expands to seatbelt measurement, forming relevant findings for effective or ineffective detection. In the framework of two-wheelers, the approach varies, reliant on the Canny Edge Detection technique and Hough Line Transform to recognize helmets, forming related outcomes when a helmet is identified or not present. This methodical strategy, applying grayscale conversion and sophisticated algorithms, displays the system's flexibility in addressing varied circumstances, displaying its potentiality relevance in augmenting safety actions through automated image assessment. The output for seatbelt and helmet detection is visually presented through the inclusion of esteemed images shown in Fig.3.

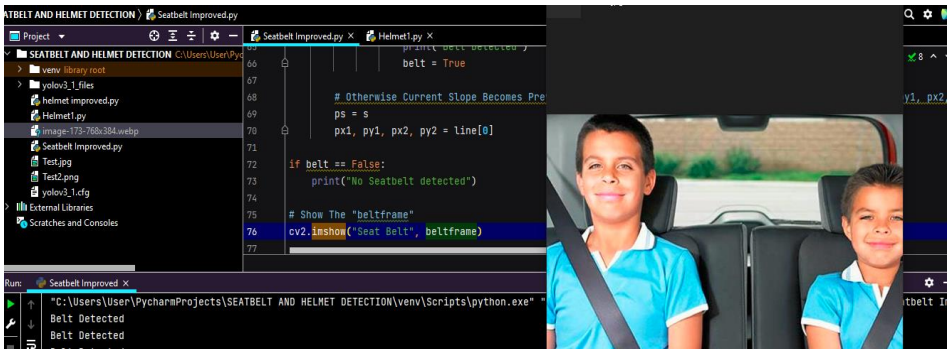


Fig.3 (a) Output for Seatbelt detection

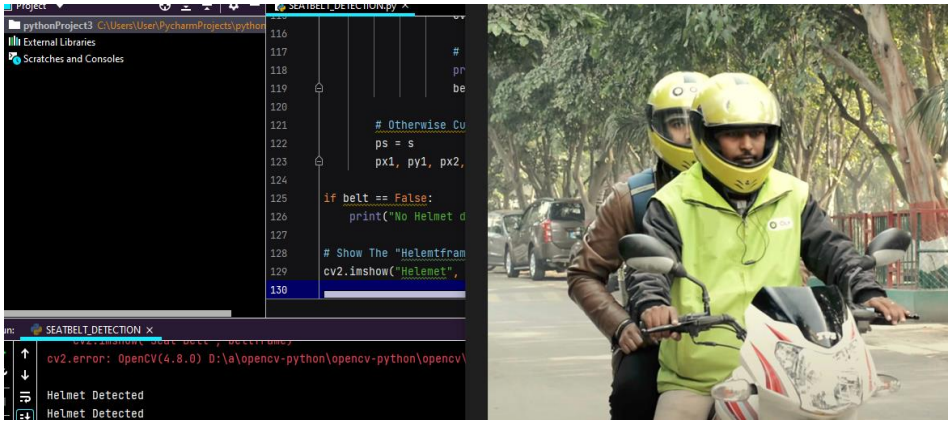


Fig.3 (b) Output for Helmet detection

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Preprocessing

This pre-analysis approach ensures that subsequent examinations operate on optimized and polished image data, thereby enhancing to the overall resilience and accuracy of the system.

Localization

This method explicitly discerns and isolates the delegated region necessary for coming analyses.

Evaluation Metrics

Table 2: Performance Metrics for Seatbelt and Helmet Detection

Metric	Seatbelt Detection	Helmet Detection
Precision	0.90	0.86
Recall	0.78	0.76
Accuracy	0.88	0.82

In the advocated technique for seatbelt detection, the model accomplished a precision record of 0.90, demonstrating the system's expertise in correctly detecting seatbelt appearance. The matching recall valuation of 0.78 confirms its comprehensive record of authentic seatbelt cases. The gross accuracy for seatbelt detection, state at 0.88, emphasizes the model's vigorous performance. In reference to helmet identification, the proposed structure demonstrates applaudable precision of 0.86 and a recall of 0.76, emerging in an aggregate accuracy of 0.82. These measurements underline the model’s effectiveness in distinctive a concordant stability between precision and recall, securing accurate identification of seatbelt and helmet instances while reducing the event of false positives and negatives. The accomplished accuracy measurements highlight the reliability of model in realistic situations, supporting its suitability in real-life scenarios. The performance metrics Table for seatbelt and helmet detection is shown in Table 2.

6. Conclusion

In overview, this investigation attempts to improve road safety with an advanced system, expanding its implementation transcending just roads. Its adjustability envisages incorporation into various conditions, boosting security in occupied regions and reinforcing crucial structures such as airports. Stimulated by the performance of Artificial Intelligence, the amalgamation of cameras, sensors, and cutting-edge approaches precedes an innovative digital stage ready to smoothly incorporate into the routine lives of the soon-to-be age group. This vital intersection

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highlights our duty to inventive for the collaborative harmony of the ongoing and upcoming, promoting a secure and top-notch realm where innovative techniques maintain sustained precaution and smartness.

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Development of Chatbot for Medical Healthcare using Artificial Intelligence

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Abstract

The use of artificial intelligence (AI) in healthcare is becoming more prevalent these days. In such an instance, AI-based chatbot platforms might operate as an automated chatbot system that supports health, teaches, and may even encourage behaviour modification. To forecast intake, it is necessary to figure out why people utilize healthcare chat bots; nonetheless, not much research have shown that these chatbots are widely accepted. The purpose of this study was to investigate participant willingness to interact with chat bots for medical treatments controlled using AI. India's population is expanding, its birth rate is rising, and its death rate is decreasing because of health care developments. Nevertheless, the country is short of enough doctors to fulfil the country's growing need for medical professionals.

Artificial intelligence systems known as chatbots converse with users using conversational language. To determine the sentence keywords, generate an investigation conclusion, and respond to a given research, most the chatbot saves the data in the database. N-gram, TFIDF, and cosine correspondence are used to calculate ranking and sentence similarity. Each term in the input you have provided word is assigned a score, and additional similar thoughts are going to prove based on the specified query. When a question is given to the chatbot, but it cannot understand or it does not in the database, it is handled by the expert software, a third party.

Key words: Chatbot, AI, SVM Algorithm

Introduction

People have become dependent on internet searches in recent years to find solutions to all their problems. This encourages people to research both general subjects and personal health-related issues. But individuals fear mistake when they looked about their ailments on Google, as most searches lead to with perhaps erroneous information and making consumers unnecessarily paranoid. In response to those needs, numerous technologies are developed by humans to Individuals receive the most precise diagnosis for their illness. Making a couple among them. A questionnaire with a yes/no response method. It is helpful, nevertheless, because of a few since many diseases share very identical symptoms, we cannot depend solely on this yes-or-no system since additional details must be provided to acquire.

Another is building websites; however, a medical webpage has become crucial in this morning's internet environment and that there are numerous forums available to address user-provided questions. The demand for a trustworthy and precise diagnosis has led to the emergence of a new class of healthcare technology known as Medical Chatbots [6]. The primary goal in

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developing this chatbot is to simulate human conversation. To provide patients with the finest diagnosis, to add to its already substantial amount of understanding of medicine, a chatbot also makes use of the ever-expanding collection of inquiries related to health. Many scenes that appear to be unchanging include minute details that are hidden from view.

Theoretical Background

To figure out how to utilize this technology, Bohle et al [8] plan to create an "empathetic" embodiment chatbot based on artificial intelligence that is able to find, retrieve, evaluate, and convey health-related data as well as converse with healthcare professionals in natural language and "voice" by utilizing 3D motions and movements of the face. Additionally, a medical chatbot made use of a research prototype, 'Bonobot' was created to communicate the sequence all throughout an argument [9]. A chatbot with a few additional features is proposed by Kumar et al.[10] input collection and data pre-processing, medical terminology detection, mapping pertinent documents, and answer and solution generation. NLP as well as natural language processing text transformed into structured data for the purpose of choosing a likely response [11].

Text transformed into structured data so that a likely response can be chosen. Sentiment analysis, tokenization, named entity recognition, normalization, and dependency parsing are some of the steps. Sentences were broken up into terms using the NLTK library, which also reduced words to their stems. Text classification is done using multinomial Naive Bayes. Every word is handled independently by this classifier and subsequently arranged into two dictionaries: corpus words and class words. Tokenized, stemmed, lowercased, and converted into training data is every word. A general rating for the variety of matching words is generated for each class. If the incorrect training material is used, a lot of knowledge may be lost.

Methodology- SVM training algorithm shown in figure 1 used to develop a model that predicts whether the test image belongs in this class or not [5]. SVM has an extremely elevated CPU expenditure and necessitate an immense quantity of data to train it for identifying an appropriate margin.

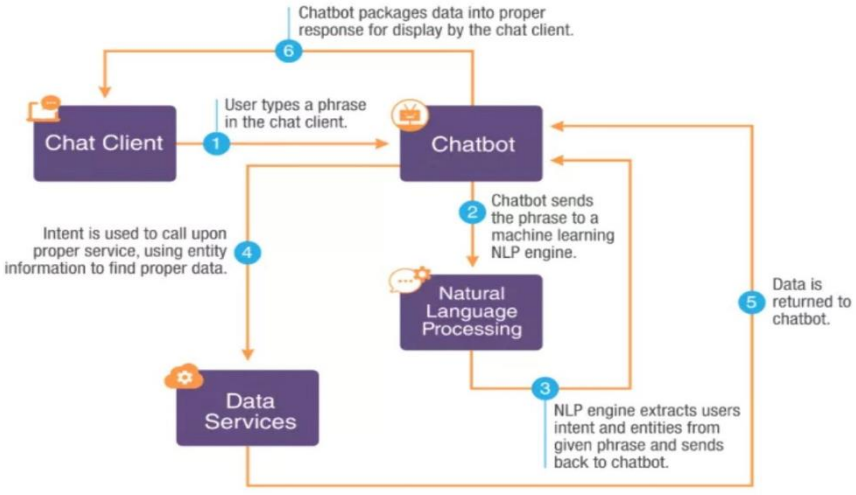


Figure 1. SVM Algorithm.

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The data that are indistinguishable from the input are transferred to an extremely dimensional characteristic space, where a high-dimensional plane may separate them.

Training SVM classifiers takes less time. The SVM algorithm has approximately ninety-four percent higher precision than the Naive Bayes and KNN methods combined.

Another text processing method suggested the apriorist algorithm with seq2seq. An encoder plus a receiver is the two an RNN that collectively make up the seq2seq model. One word at a time, the encoder reads in an expression and then analyses it.

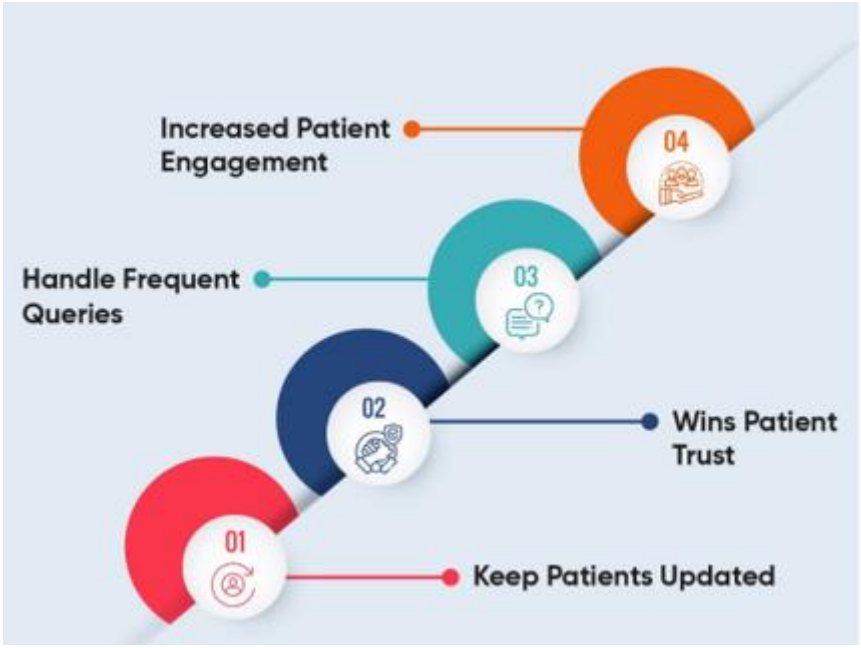


Figure 2. Benefits of Medical Chatbot

Result and Discussion

Multiple strategies are employed for a chatbot. The methods they employ fall into the categories of information mining, comparison keyword, machine learning, NLP, Braun and Clarke, and data mining. A research chatbot developed by Ghosh et al. [3], makes use of data mining and natural language interpretation. To produce naturally comprehensible responses form people, NLP (natural language processing) depends on templates that are preset and software initiative. We discover believe group education will be beneficial for a few reasons, including each the framework uses somewhat varied subsets of the data to generate predictions, so it covers a certain amount but not all of facts. Additional studies, also making use of using a supporting vector neural network method to perform machine learning. From this manuscript, we demonstrate that SVM can identify the best discriminating feature between both groups. Hyperplane that reduces mistake for a hidden pattern. This is what makes up Regarding RQ1, which method is best for a chatbot?

Language processing and algorithmic learning are the matchmaking algorithms that compose the medical chatbot. Language interpretation. Some of the several algorithms that are employed

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by machines learning techniques include binary regression, categorization, artificial neural networks, supervised as well as unsupervised learning, and together learning.

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Classification of Thyroid Disease using Web Application

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Abstract

The thyroid, situated in the neck's front, functions as an endocrine gland producing crucial thyroid hormones vital for overall health. Early detection of thyroid disorders significantly reduces risks such as mortality, recurrence, adverse effects, and the necessity for extensive surgical interventions. This study use a Random Forest algorithm to predict patients' susceptibility to thyroid diseases. It utilizes a Python Flask-based web application to interface with the trained model, enabling users to assess their risk of thyroid ailments conveniently.

Keyword

Random Forest Algorithm, Web application, Python Flask, Hypothyroid Disease, Hyperthyroid Disease

Introduction

The thyroid plays a crucial role in the endocrine system as it regulates metabolism, the process of converting food into energy. Among endocrine glands, the thyroid gland holds significant importance.[1] Research indicates that in India alone, 42 million individuals suffer from thyroid issues, predominantly women affected by hypothyroidism. The ratio of affected women to men is as high as eight to one, highlighting the urgency for intervention due to incorrect thyroid hormone production in women.[2]

Hypothyroidism and hyperthyroidism are prevalent types of thyroid disorders resulting from either overproduction or underproduction of thyroid hormones. When endocrinologists monitor patients, machine learning methods prove invaluable in enhancing diagnostic capabilities. Recent studies demonstrate the efficacy of classification and prediction techniques in diagnosing various health conditions such as heart disease, diabetes, and Parkinson's disease. This approach significantly reduces the time and resources required for patient treatment.[3]

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This study proposes employing machine learning to determine optimal treatment adjustments for patients.[8] A Python Flask-based web application is under development to aid doctors in predicting thyroid diagnoses, as depicted in Figure 1.

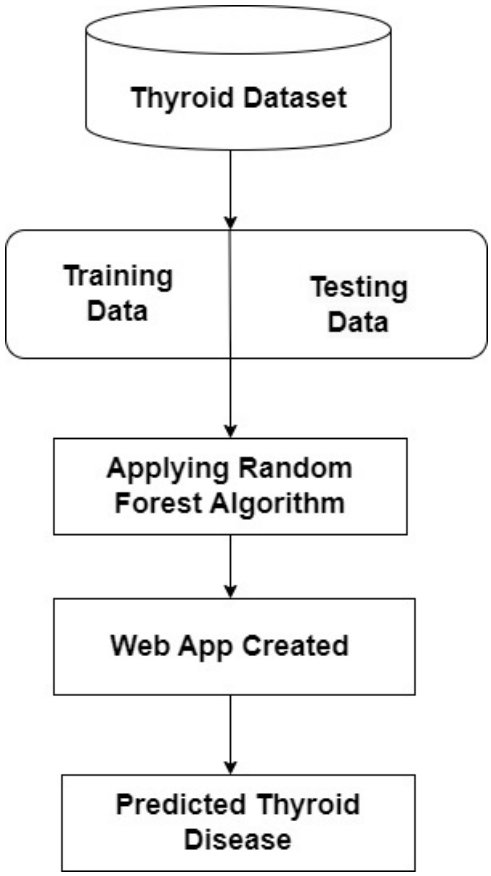


Fig.1. Data Flow Diagram

Definition of the problem

Thyroid diseases are on the rise in India, affecting approximately one out of every ten adults. With an estimated 42 million individuals affected, the prevalence of thyroid disorders is significant. The process of predicting thyroid disorders typically demands considerable time and expertise from doctors, as accurate evaluation often requires seasoned medical professionals. To alleviate this burden and aid doctors in disease prediction, a Python Flask web application has been developed, aiming to streamline the process and reduce the workload of healthcare professionals.

Related Studies

Early identification of thyroid diseases, whether hypothyroidism or hyperthyroidism, is facilitated by a web application. Literature review was conducted using databases of peer-reviewed articles such as Google Scholar

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and Scopus, focusing on works published within the last five years. Relevant articles were identified using search terms like "Thyroid disease," "Web application," "Python Flask," and "Machine Learning," resulting in the selection of four key papers for our study.

In their 2023 publication, Sultana et al. presented a machine learning system employing feature selection to categorize thyroid diseases and identify associated risk factors. Six ML classifiers including Gradient Boosting, Support Vector Machine, Ada Boost, Decision Tree, Random Forest, and K-Nearest Neighbors were utilized for model training. The study also incorporated the smote method to handle imbalanced data and employed feature selection algorithms like Boruta, RFE, and Lasso. The resulting machine learning model demonstrated proficiency in diagnosing thyroid conditions.

Selvaraj et al. (2022) focused on utilizing support vector machines for thyroid disease prediction. Their dataset was sourced from an open-source machine learning repository, and various charts such as pie charts, count plot charts, and histogram charts were employed to visualize gender-based data distribution. The study also applied the smote technique to address data imbalances and proposed the use of ultrasound images for future predictions.

Aversano et al. (2021) discussed the application of machine learning in predicting thyroid disease, utilizing a specialized dataset from a hospital in Naples. Ten different machine learning algorithms were employed to assess their effectiveness. However, the study highlighted the dataset's limitations and proposed enhancing its quality through expanded collection efforts.

Chandan et al. (2021) utilized machine learning to determine the type of thyroid disease a person may have and developed a web application to provide disease-related information to users. Algorithms such as Support Vector Machine, Logistic Regression, Decision Tree, K-NN, and ANN were utilized. The study aims to incorporate ultrasound imaging for predicting thyroid diseases not detectable through blood tests in the future.

Enhanced Random Forest Classifier for Classification

The enhanced Random Forest technique has been applied to classify thyroid disease [9]. Random Forest comprises a collection of classifiers organized in a tree-like structure. Each tree within the forest contributes a single vote, assigning the most likely class name to each input [10]. This method is swift and robust, even in the presence of noise, and proficient at identifying non-linear trends in both numerical and categorical data. The Random Forest algorithm operates in two stages, as depicted in Figure 2. Initially, N decision trees are combined to construct the random forest, followed by predictions being made for each tree created in the first stage. To show the process, the following steps can be followed:

Step 1: Randomly select M data points from the training set.

Step 2: Build decision trees based on the selected data points.

Step 3: Each tree yields a distinct classification.

Step 4: The final outcome is determined by either majority voting or averaging for classification purposes.

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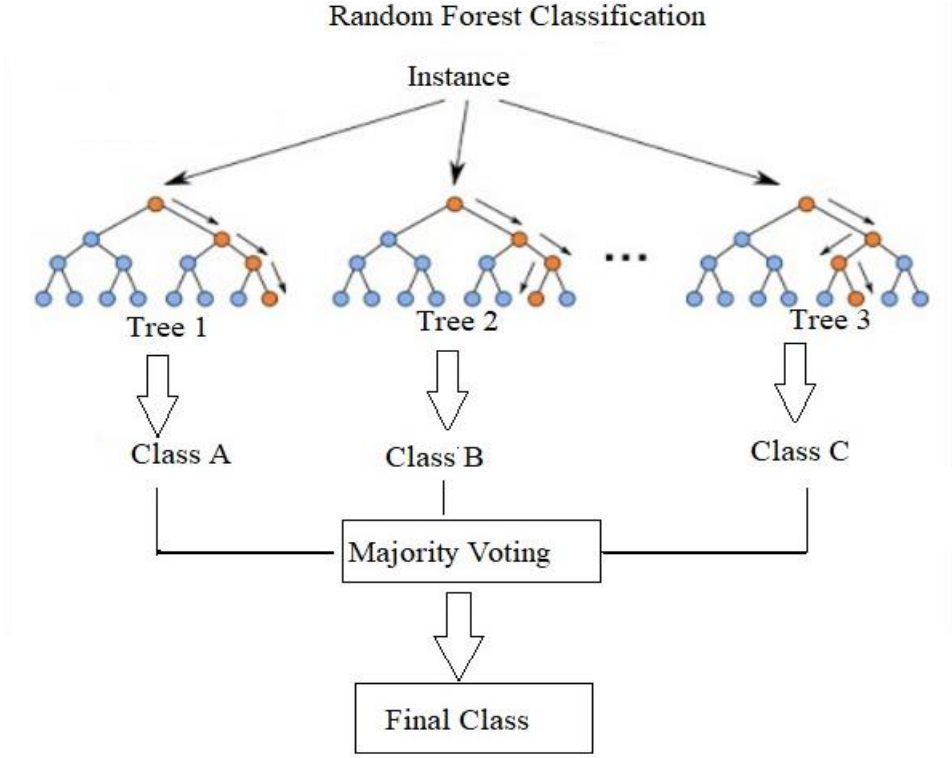


Fig. 2. Random Forest Classification

Proposed Approach

The proposed methodology aims to forecast the treatment of thyroid disease based on patients' characteristics. Initially, we outline the process of compiling the dataset. Subsequently, we identify and finalize the features, as presented in Table 1. Finally, we utilize the random forest algorithm for thyroid disease prediction in this study and develop a web application for its implementation. The web application, constructed using Python Flask, serves to predict thyroid disorders such as hypothyroidism and hyperthyroidism. Designing the application is a critical aspect of system architecture, detailing the integration of various program components. Typically, a web program adopts a client/server architecture, distributing the logic between two distinct layers. A conceptual design is employed to illustrate the prototype of a web application geared towards detecting thyroid issues [11].

Table 1 Thyroid Dataset Description

Attribute Name	Value Type	Attribute Name	Value Type
Age	Continous	Goitre	*Yes, No*
Sex	M,F	Tumor	*Yes, No*

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On Thyroxin	Yes, No	Hypopituitary	Yes, No
On-Antithyroid medication	*Yes, No*	Pysch	*Yes, No*
Sick	*Yes, No*	TSH	*Yes, No*
Pregnant	*Yes, No*	T3	*Yes, No*
Thyroid Surgery	*Yes, No*	TT4	*Yes, No*
L131 treatment	*Yes, No*	T4U	*Yes, No*
Query Hypothyroid	*Yes, No*	FT1	*Yes, No*
Query Hyperthyroid	*Yes, No*	Class	Target Class
Lithium	*Yes, No*		

The web application created for predicting thyroid disease after feature reduction is shown in Figure 3.

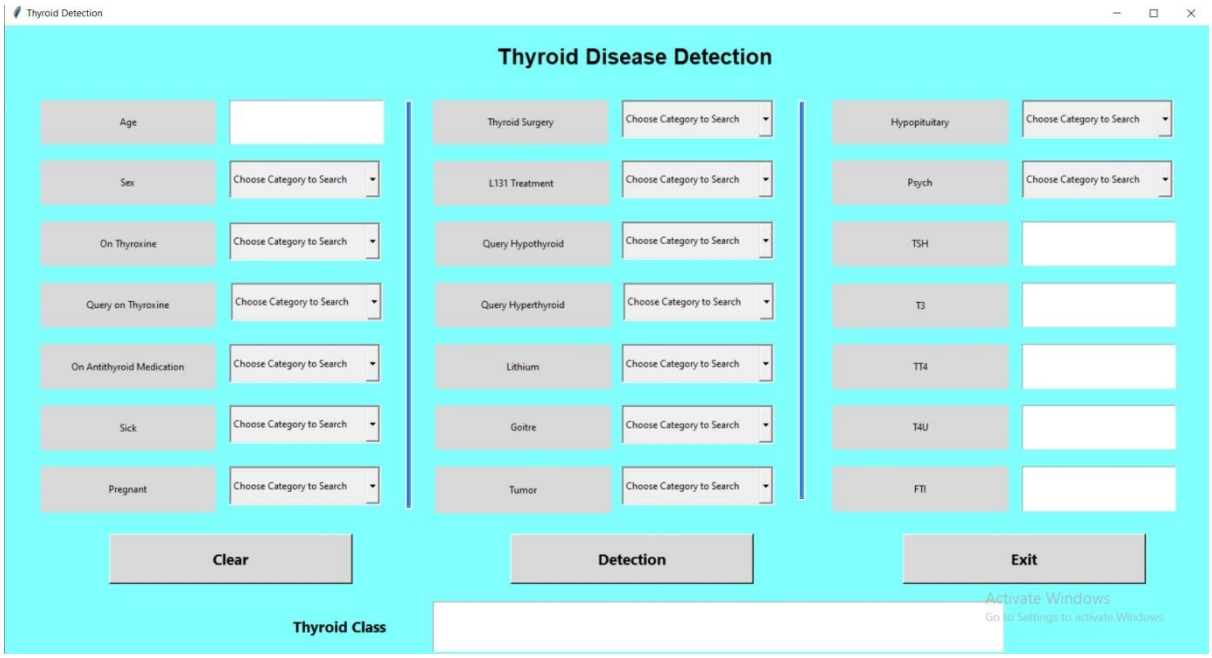


Fig. 3. Prediction of thyroid disease using Web Application

The prediction of hypothyroid disease and hyperthyroid disease has shown in figure 4 and figure 5.

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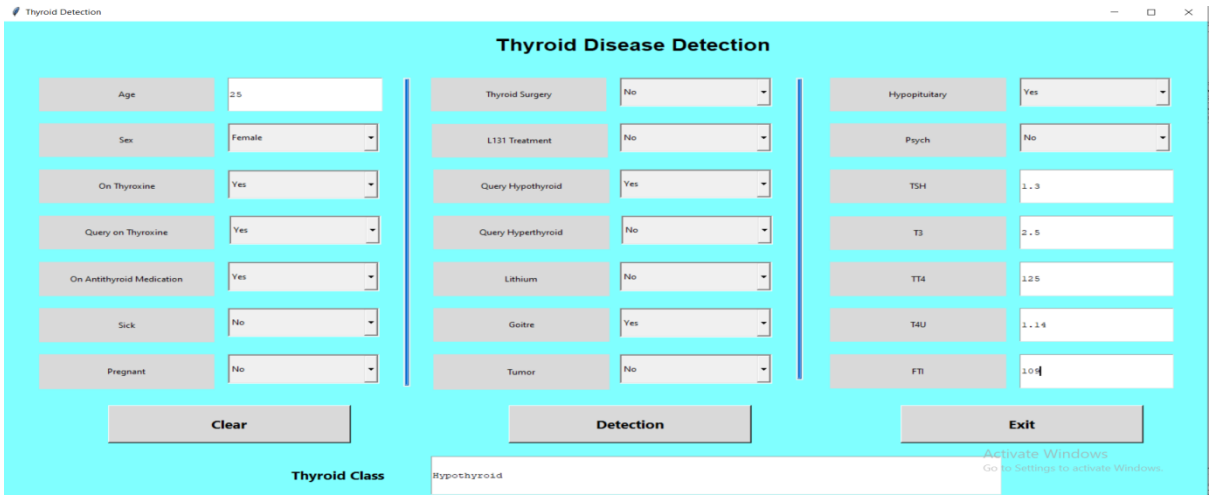
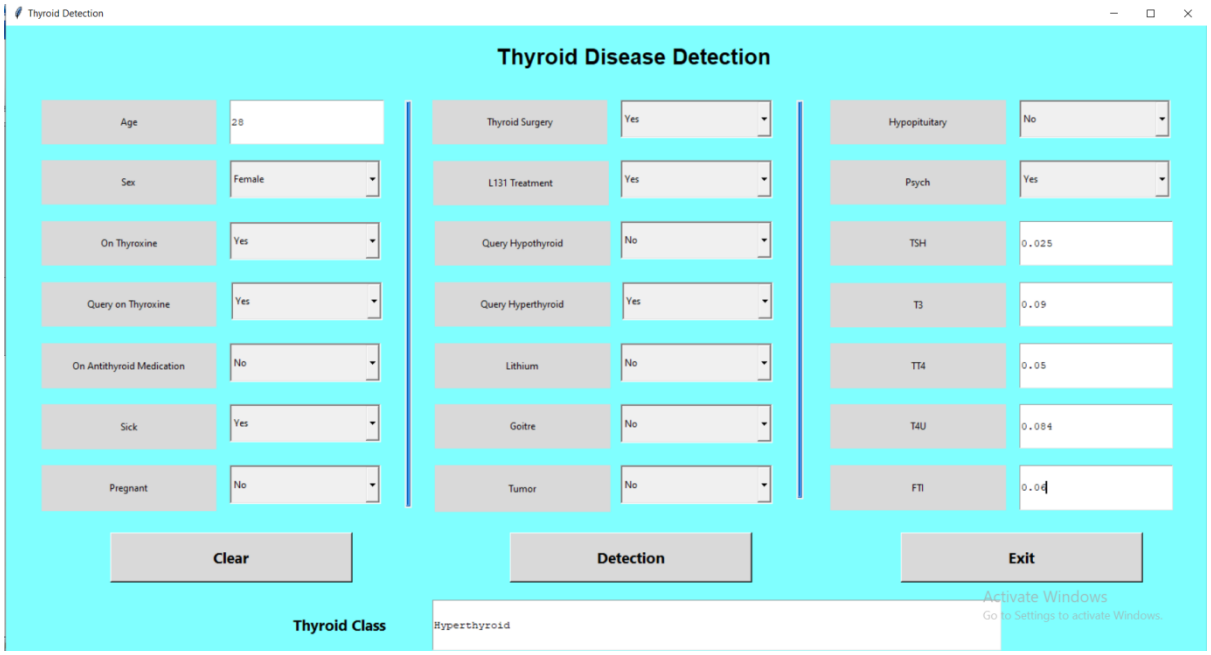


Fig. 4. Prediction of Hypothyroid Disease



Fg. 5. Prediction of Hyperthyroid

Conclusion

This paper aims to present a precise and efficient machine learning solution for detecting thyroid disease, which has become increasingly prevalent in recent years. The need for robust automatic prediction models in thyroid detection is paramount. Our approach focuses on developing a sophisticated and precise method for identifying thyroid diseases using a web application. We utilized the Random Forest algorithm to train our dataset, improving the accuracy of thyroid disease detection. Based on user input, the application can determine whether an individual is categorized as normal, hyperthyroid, or hypothyroid.

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Unravelling the Nexus of Workforce Agility and Employee Engagement in the Dynamic Landscape of the IT Industry

Abstract

In today's rapidly changing business world, agility is a crucial attribute for companies seeking to gain a competitive edge. This study aims to identify the dimensions of workforce agility and explore its impact on employee engagement, based on the resource-based view theory. The study collected data from 235 employees in the information technology (IT) industry and used SMART PLS-SEM v4.0 software to analyze the data. The study found that proactivity and adaptability, two factors of workforce agility, have a significant impact on employee engagement, while resilience has no significant effect. Together, these three factors explain 68% of the variance in employee engagement. This holistic model provides a comprehensive understanding of the complex interactions between different components of workforce agility and their combined impact on organizational success.

Keywords

Employee engagement. knowledge workforce, human resource agility, and learning environment.

Introduction

To attain a competitive advantage in this dynamic environment, agility is one of the attributes that play an essential part in a firm's existence and growth in this environment [1], because an agile organization can efficiently cope and integrate itself to any rapid and uncertain in the environment [2]. In a Deloitte survey of over 10,000 organizational and human resource leaders from 140 countries, 94 percent said that "'agility and collaborative effort' are vital to their business survival". Agility in human resource (HR) refers to HR's capacity to adjust efficiently and decisively to changes in business needs and updates. The capacity to cope with external factors is the most significant issue for agile organizations [3]. One of the other purposes of an agile organization is to satisfy customers and employees. Since the HR department is not typically meant to directly provide value to the consumer, it is frequently chastised for its slowness to act quickly, resulting in employee dissatisfaction. As a result, firms must engage and empower human resources (HR) to be more aware of and respond to evolving technology and business requirements to remain competitive and attract top talent. When top management prioritizes the satisfaction of customers and creates a competitive advantage in the market, it is said to be agile. Agile HR (workforce agility) must spend in engaging with its staff frequently to understand and respond to their concerns. Dynamic personnel policies and initiatives are required to respond to aligning employee demands and market situations. There is no denying that the information technology (IT) sector is the main force behind economic growth and employment creation in emerging nations. This claim is supported by the industry's rapid hiring, with the Indian Brand Equity Foundation reporting that in the fiscal year 2022, the sector

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added 0.445 million new employees, bringing the entire workforce to 5 million. The rapidly evolving field of technology, which is typified by breakthroughs like artificial intelligence (AI), machine learning (ML), and human resource analytics (HRA), has placed a great deal of pressure on enterprises [4]. As a result, companies are forced to invest in their staff with vision by starting ground on cutting edge employee-centric projects. These programmes enable staff members to pursue lifelong learning, upskill, and reskill.

The ideal modern worker must be agile and nimble, possessing a range of skills including technological aptitude, critical thinking, creative problem-solving, adaptation, and the subtle art of interpersonal and emotional intelligence [5]. Moreover, it has been noted that the emerging market IT industry often struggles with a lack of qualified IT professionals. Therefore, companies need to offer competitive remuneration packages, avenues for professional advancement, and limitless learning opportunities to lure and keep talent [6]. This means that the concept of employee engagement needs to be thoroughly investigated. The degree to which workers are emotionally invested in and dedicated to their work, the organisation, and its objectives is referred to as employee engagement. It entails establishing a welcoming workplace where staff members have a sense of support, worth, and alignment with the organization's goals and principles. Schaufeli et al. [7] defined employee engagement is a positive fulfilling state of mind which is characterized by vigor, dedication and absorption. Vigor is defined as having a lot of energy and mental toughness. Vigorous individuals are passionate, proactive, and willing to put effort into their professional activities. The feeling of inspiration, zeal, and importance that workers have for their work is known as dedication. Employees who exhibit high levels of involvement and dedication are emotionally invested in their job and are prepared to devote time and effort to the attainment of organisational objectives. Being completely focused and absorbed in one's job is known as absorption.

While previous studies focused on the role of technology architecture to foster agility, more current viewpoints highlight the importance of human resources [8]. The majority of the research has examined the benefits of agility for innovation [9] and economic performance, but none of the studies have examined the relationship between workforce agility and employee engagement especially in the high-tech industries (IT) where rapidly digital transformation, and being innovate is of prime concern.

Theoretical underpinning and hypotheses development

Workforce agility

Yusuf et al. [10] examined different attributes that must-have for an agile organization, the employer should hire and retain skilled employees, keep motivating them, and involve them in decision-making. Employees working in the organization should be compatible to work in a different environment as the organization needs, should aware about a different culture, different languages, etc. There should be top management support to have agile people in an organization, open communication, a flexible environment, and empowering employees [11]. [12], investigated the impact of employee empowerment on the financial performance of

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companies and found a significant effect on an organization's improved performance. The work in the IT industry is based on technology, have to create a learning environment so that they can work with more efficiently. HR must focus heavily on learning and motivating staff in acquiring or introducing innovative skills to keep up with external factors and stay viable. Workers that prioritise learning are more invested in their work; they seek out difficult tasks that spark interest and intrigue, take time to reflect on their own lives, and participate in creative learning [13]. Employee engagement was 20–30% greater in organisations with high agility than in those without, according to a survey report by Mckinsey [14]. A profound sense of independence, power, and significance are likely to emerge in workers with high agility; these traits are linked to higher levels of employee engagement. Mckinsey [15] reported that it[i] is imperative for employers to recognise the distinct workforce segments such as initial stages employees, late-stage employees, working parents, and unconventional workers, inside their organisations, and create value for staff propositions that are customised for each of these groups. Giving individuals money, a work-life balance, or a sense of purpose is not the goal; rather, it is about offering any or all of those things in the amount that best fits a specific market group. Past studies emphasized on different attributes of workforce agility and different characteristics of an agile person which is shown in table 1 and 2 respectively.

Table 1: Factors of Workforce agility

Sr no	Determinates of Human resource agility	References
1.	Create a learning environment	Sohrabi et al., 2014; Asari et al., 2014; Sherehiy, & Karwowski, 2014
2.	Ensures flexibility at the workplace	Breu et al., 2002; Dyer, & Shafer, 1998; Gunasekaran, 1999; Sharifi, & Zhang, 1999; Lin et al., 2006; Yusuf et al., 1999; Sherehiy et al., 2007
3.	Awareness and Adaptability	Goldman, 1995); (Jackson, & Johansson, 2003; Hamel, & Prahalad, (1990); Thani et al., 2021; Antonacopoulou, 2000; Davydova et al., 2016
4.	Digitize the workforce	Lin et al., (2006); Yusuf et al., (1999); Sherehiy et al., (2007)
5.	Cooperation and collaboration	Van Oyen et al., 2001; Shahsavari-Pour et al., 2021; Yusuf et al., 1999

Source: Author's compilation

Table 2: Characteristics of an agile person described by previous literatures

Reference	Dimensions
Dyer and Shafer's 1998	Business and value-driven, adaptive, focused, proactive
Shafer et al.'s 2001	Taking the above factors, added resiliency

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Breu et al.'s 2002	Smart working, employee empowerment, ready for modifying or developing competencies, support of top management as well as technology
Dyer and Shafer's 2003	Adaptive, generative, proactive
Sheehy et al.'s 2007	Positivity toward changes, new ideas, and technology. Tolerance for ambiguous and unprecedented conditions. Managing Stress (resiliency), adaptability, and proactivity
McCann and Selsky's 2012	Result-oriented
Muduli's 2013	Self-development, adaptability, collaboration, information, speedy

Source: Author's compilation

Based on previous literature, the study identified characteristics of agile people, overall and can be adopting any kind of industry. An agile person should have an anticipation personality-problems related to change could be addressed by him/her, adaptability- quickly adapt the changes that required in business such as learning new technology, collaborative work, resiliency- positivity towards unprecedented change, self-awareness- dedication for self-improvement and self-education and mental and psychical wellbeing and at last, goals oriented-alignment and understand the culture of business and future opportunities.

Alavi [16] emphasised that workforce agility is important to consider in understanding manufacturing flexibility and found that agility improves the process of new product, mix, and volume flexibility. Muduli and Pandya, [17] found psychological empowerment is important aspect of an organization's effort to foster workforce agility. Psychological empowerment refers to the inner drive of the employees that propels towards their goals and jobs. It defined workers who possess autonomy and control over the way they carry out their jobs [18]; [19]. Al Daboub et al. [20] revealed a positive relationship between HR (human resource) practices and psychological empowerment which further influence the employees to be innovative in their work behaviour. A recent survey done by Muduli and Choudhury [21] explored the factors of agility through systematic literature review in terms of digital transformation. The process of digital transformation is influenced by agile attitude traits including a team-oriented viewpoint, self-efficacy with computers, contradiction hatred. The IT industry is strongly involved in both the adoption of agile approaches and the goal of digital transformation. Taken as a whole, they facilitate creativity, adaptability, and long-term success by helping companies negotiate the intricacies of the contemporary business environment. Franco and Landini [22] surveyed on private sector employees in 28 countries and found that higher level agility has strongly related with employee commitment and committed employees are more likely to innovate in their work. To remain competitive in an environment that continues to evolve quickly, adaptable organizations promote creativity and innovation. A culture of ingenuity and creativity that stimulates workforce agility is fostered by engaged employees, who are more inclined to provide novel concepts and are willing to take challenges.

In competitive markets where organisations must adapt to constant and unexpected change, workforce agility or HR agility has been suggested as being crucial for organisational survival. Workforce agility is the ability of employees to deal with change, respond to it, and adapt by

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making use of the company's resources [23]. An adaptable staff has the power to influence a company's environment. This flexible workforce may predict and anticipate the dynamics of the work environment through leveraging its expertise and skills [24]. Sherehiy [25] defined the three dimensions of workforce agility namely, 1) proactivity which refer to as foreseeing issues arising from the change, initiation of efforts that result in work improvements and the resolution of issues relating to change, addressing of issues pertaining to change. 2) Adaptability refers to transforming or adapting oneself or one's actions to better suit a new setting. 3) Resilience is the ability to function effectively under pressure, even in the face of a changing environment or when tried-and-true tactics and solutions have not worked.

Proactivity and employee engagement

Organizations should focus on an 'evolving' learning approach. Learning does not necessarily have to be instructor-led; it can instead be experiential. Offer the opportunity for people to take on projects and assignments to learn outside of their normal activities Sohrabi et al., [26]; Asari et al., [27]; Sherehiy, & Karwowski, [28]. Flexibility as HR practice could be the way to involve them in organization goals and to satisfy their jobs. Ability to solve issues and quickly adopting the change in the organization and flexibility among employees is the dimension of flexibility given by authors Breu et al.[29]; Dyer, & Shafer, [30]; Gunasekaran, [31]; Sharifi, & Zhang, [32]; Lin et al., [33]; Yusuf et al., [34]; Sherehiy et al., [35]. Goyal et al. [36] found the positive relationship between HR flexibility and employee engagement. A proactive personality is one that is inclined to consciously alter surroundings to effect significant change. Employees that are proactive often gather job resources to inspire themselves to do well at work Demerouti et al.,[37]. Job resources such as autonomy, organizational support and performance feedback are positively related with employee outcomes like work engagement Bakker et al., [38] and employee performance Tisu et al., [39]. Bakker et al. [40] demonstrated that proactive personality positively relates with work engagement through job designing. Proactive personality of employees is greatly influenced by the proactive environment of the organization. Proactivity may be viewed as a valuable resource from an resource based view (RBV) standpoint if it is uncommon and difficult for rivals to imitate. Organizations that promote a proactive culture and provide employees with the liberty to act on their own initiative have a resource that strengthens their competitive edge. Agile organization enable them to be proactive in their work, which ultimately engage them in the long run. Zahoor [41], found proactive nature of frontline staff members greatly improves their work engagement, which in turn has a good driving effect on their customer service recovery performance. The proactivity-engagement dilemma has received little study attention despite these preliminary findings. Given the significance of personality traits for involvement as emphasised by past literature (Bakker & Demerouti [42]; Saks [43], it seems to be an important endeavour need to look into the relationship directly between proactive environment (as factor of agile organization) and employee engagement in the IT industry. Therefore, framed following hypothesis:

H1: there is a positive influence of proactivity on employee engagement

Adaptability and employee engagement

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An agile culture is one in which staff' abilities, expertise, and experience are the most essential variables in differentiating enterprises and corporations. To attain agility, the companies require agile people Goldman [44], Holbeche [45]. Agile people are those who are proactive and are ready to accept or implement changes. The characteristics of agile people is defined in table 2 with reference. Employee knowledge and innovation are the two most important aspects of agility Jackson, & Johansson [46]. Studies Hamel, & Prahalad [47] specified that people must be nimble to deal with changes inside the production system as well as to adapt the system to new circumstances. Adapting is the act of undertaking adaptive behaviours in response to changing conditions. Career adaptation entails overcoming obstacles in the workplace, adjusting to work-related catastrophes and unforeseen circumstances, and mastering duties related to vocational development Hirschi & Valero, [48] Savickas & Porfeli, [49]. Consequently, linked "views" or "behaviours" that people employ to deal with assigned tasks and shifting work environments are considered adaptive responses. Tladinyane and Van der Merwe [50] surveyed on employees working in insurance companies of South Africa revealed that career adaptability is strongly linked with employee engagement. Employee well-being is thought to be the ultimate outcome of self-fulfilment and personal growth, but work engagement is unquestionably one of the most significant strategies to reach personal development through elevated diligence, pleasant affect, and inspired cognition in the workplace Yang et al. [51]. Paying attention to the self-development strategy within the firm is one of the most significant tools for fostering an agile culture and inventive human resources Thani et al. [52] Antonacopoulou [53] Davydova et al. [54] The self-development approach is defined as continuous improvement, which is also helpful in promoting human capital and is based on individuals' personality, personal drive, and self-satisfaction Yusuf et al. [55] The agile enterprise is viewed as the winning strategy for becoming national and international leaders in an ever-increasingly marketplace of rapidly changing client expectations Lin et al.[56]. Yang et al. [57] found the positive influence of career adaptability on employee well-being via employee engagement. Employees with flexibility are especially sensitive and engaged in this volatile and unstable work environment, since they are prepared to respond appropriately with an adaptable adjustment Goyal et al. [58]. Additionally, adaptability among staff members can have a good impact on their attitudes and work engagement. Adaptability may be viewed as a catalyst for raising employee performance standards and improving job engagement, which in turn spurs innovation and advances the company Urbini et al. [59]. Proactive and flexible workers are probably more involved in their work. Workers who are supported in taking initiative and adjusting to changes are more likely to feel that their work has purpose, which raises engagement levels. Based on RBV perspective, proactive and adaptability are internal organizational resources which enhance engagement level of employees. Based on literature present study framed the following hypotheses:

H2: there is a positive influence of adaptability on employee engagement

Resilience and employee engagement

Agile employees perform well because they are adaptable and can do more things in less time. Their collective efforts will result in organizational harmony and tasks of better calibre and cheaper cost. Agility allows staff to do jobs more rapidly and reduces the length of service

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operations. The agility of the workforce would increase internal quality (defect reduction and duplication) as well as external quality (satisfying the needs of stakeholders) and assist the company in fierce competition Muduli [60]. Employee agility improves service flexibility and allows the company to provide a broader range of services Shahsavari-Pour et al. [61], Yusuf et al. [62]. Agility is a set of qualities and talents that enable an enterprise to remain viable in an atmosphere defined by constantly changing and unpredictability. The potential to flourish in a continuously changing and uncertain environment is referred to as agility. So, agility denotes flexibility and the ability to respond to environmental changes Gligor et al. [63]; Hamel, & Prahalad, [64]. Resilience is the degree to which a person can handle difficult situations and bounce back from the worst Sherehiy & Karwowski [65]. Even in the face of setbacks resilient people typically approach life with optimism. Past studies have associated the factors of agility with mindful organizing and safety performance in the health care sector Saleem et al. [66]. A workforce that is agile is thought to be proactive, adaptable, and resilient while handling unusual and unanticipated situations Sherehiy et al. [67]. As demonstrated by Breu et al. [68] and Sherehiy et al. [67], it may adapt better to uncertain changes and perform better in competitive contexts. These include high technology sectors. Emotional and mental health are positively correlated with resilience. Workers that possess greater resilience are inclined to retain an optimistic attitude despite facing challenging. One of the main factors influencing employee engagement is mental wellness. Employees have a greater probability to be engaged, committed, and devoted to their work when they are mentally well (Robertson & Cooper, 2010; Sivapragasam & Raya, 2018). Workplaces with adaptable individuals tend to have higher levels of employee engagement because engaged workers are more willing to learn new skills and contribute to the prosperity of the organizations. Further past studies (Beuren et al., 2022; Hudgins, 2016; Kašpárková et al., 2018) demonstrated resilient workers are more likely to be satisfied with their jobs. Their capacity for stress management makes work more enjoyable for them. Pleased workers exhibit greater dedication to their organisations and are probably more involved in their jobs. There is no direct linkage between resilience workforce and employee engagement has established. Therefore, study framed following hypothesis:

H3: there is a positive influence of resilience on employee engagement

Research Methodology

Sample design: This study research design is descriptive cum analytical and used a purposive random sample design. And surveyed (n= 235) employees working in the IT industry. Purposive random sampling was employed for data collection and administration. It was used to choose IT industry workers who were responsible for providing services. Using a random sample technique, service providers in this area were identified. A relevant response rate of 52.22% was obtained from 450 questionnaires that were distributed to IT industry employees, 235 of which were returned and still usable. The minimal sample size needed to evaluate the suggested model was determined to be 74 at 15% effect size, using G*Power analysis, required number of samples for structural equation modelling (SEM) (Faul et al., 2009).

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Sample characteristics: Out of 235, 64% of employees were male and rest were female. And the majority of employees (62.1%) belong to the 5-10 experience category. And 50.8% of people graduated and the rest were post-graduated.

Measure: All the constructs were measured on a 7-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Workforce agility was measured with 15-items in which have three sub-factors namely, proactivity (6 items), adaptability (5- items), and resilience (4 items) and adapted from Sherehiy (2008). And for employee engagement 11 items having 3 sub-factors (vigor, dedication and absorption) adapted from Schaufeli et al. (2002).

Measurement model

The outer loadings should be greater than 0.7 as defined by Hair et al. (2019). The convergent reliability which was assessed by composite reliability (CR), Cronbach alpha (CA), and Rho_A should be greater than 0.7 as recommended by Hair et al. (2017). All the values are lying between the threshold value. And for convergent validity, AVE values were checked that should be above 0.5, and all values are above 0.5 (refer table 3). A more stringent criterion for assessing discriminating validity is the Heterotrait-Monotrait (HTMT) criterion, which is characterised by a correlation value between the two constructs that must be less than 0.85 (Henseler et al., 2015). All the correlated values were less than 0.85 suggesting that each factor is distinct with each other (refer table 4).

Table 3: Measurement model results

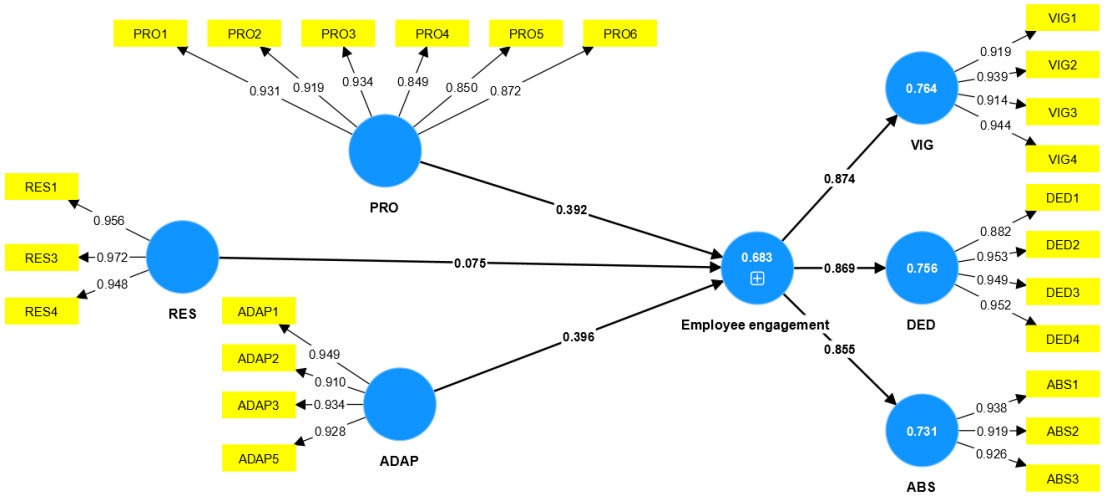
Constructs	Items	Outer loadings	CA	CR	Rho_A	AVE
Proactivity	PRO1	0.931	0.919	0.949	0.92	0.86
	PRO2	0.919				
	PRO3	0.934				
	PRO4	0.849				
	PRO5	0.850				
	PRO6	0.872				
Resilience	RES1	0.926	0.926	0.921	0.928	0.885
	RES3	0.912				
	RES4	0.928				
Adaptability	ADAP1	0.929	0.928	0.943	0.929	0.845
	ADAP2	0.910				
	ADAP3	0.934				
	ADAP5	0.928				
Vigor	VIG1	0.919	0.947	0.942	0.948	0.863
	VIG2	0.939				
	VIG3	0.914				
	VIG4	0.944				
Dedication	DED1	0.882	0.931	0.945	0.931	0.853
	DED2	0.953				

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	DED3	0.949				
	DED4	0.952				
Absorption	ABS1	0.938	0.919	0.949	0.920	0.86
	ABS2	0.919				
	ABS3	0.926				

Note: CA= Cronbach alpha, CR= Composite reliability, Rho_A= Dijkastra-Henseler' rho, AVE= Average variance extracted.
Source: Smart PLS-SEM results

Figure 1: The inner model represents path coefficients and the outer model represents outer loadings



Source: Smart PLS-SEM reults

Table 4: HTMT and Fornell Larcker results

	ABS	ADAP	DED	PRO	RES	VIG
ABS						
ADAP	0.735					
DED	0.662	0.835				
PRO	0.75	0.9	0.809			
RES	0.691	0.897	0.787	0.879		
VIG	0.716	0.616	0.628	0.621	0.546	-----
Fornell Larcker results						
ABS	0.928					
ADAP	0.689	0.93				
DED	0.621	0.793	0.934			
PRO	0.705	0.861	0.771	0.893		
RES	0.65	0.853	0.751	0.837	0.959	
VIG	0.669	0.585	0.596	0.592	0.52	0.929

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Note: ABS= Absorption, ADAP= Adaptability, DED = Dedication, PRO= Proactivity, Res= Resilience, VIG= Vigor, DED= Dedication, ABS= Absorption.
Source: Smart PLS-SEM reults

Structural model

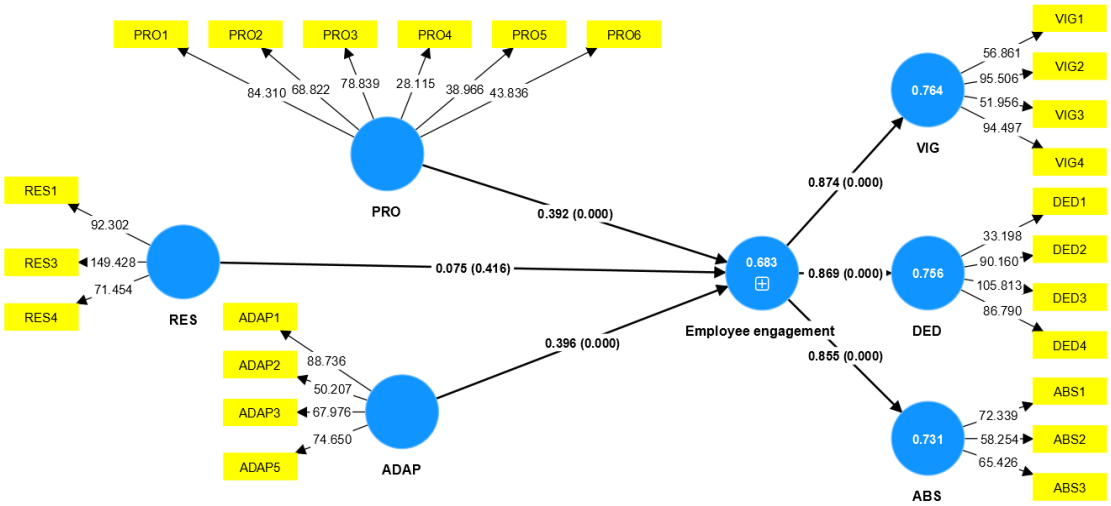
Using the bootstrap approach on 5000 subsamples, the structural relationships (Figure 1) were tested (Sarstedt et al., 2017). The study found positive significant effect of proactivity (β = 0.392) and adaptivity (β = 0.396) on employee engagement (EE), and insignificant effect of resilience (β = 0.075) on employee engagement. The present model R2 values signifies 0.683 variances on EE, with moderate to substantial values of accuracy (Hair et al., 2021). Table 5 indicates effect size of PRO on EE ($f^2 = 0.106$) is the highest among all, stating medium effect size and followed by ADAP on EE ($f^2 = 0.099$). While RES has a negligible effect size (Hair *et al.*, 2019).

Table 5: Hypothesized path relationships

Path	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Remarks	Effect size ($f^{2)}$
PRO -> EE (H1)	0.392	0.395	0.102	3.857	***	Accepted	0.106
ADAP -> EE (H2)	0.396	0.397	0.098	4.038	***	Accepted	0.099
RES -> EE (H3)	0.075	0.071	0.092	0.814	0.416	Rejected	0.004

Note: PRO= Proactivity, ADAP= Adaptability, RES= Resilience, EE = employee engagement
Source: SMART PLS-SEM output

Figure 2: Inner model depicting path coefficients and p-value while outer model represents t-value



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Source: Smart PLS-SEM results

Discussion and implication

The present study has identified the factors of workforce agility and characteristics of an agile person. When it comes to achieving success in today's competitive environment, it's impossible to do it without considering workforce agility. This study found positive significant effect proactivity (β = 0.392) and adaptivity (β = 0.396) on employee engagement, thereby accepted H1, H2 respectively. The findings consistent with the prior studies (Strobel et al., 2017; Vermooten et al., 2019; Zahoor 2020). Based on RBV theory, being proactive and adaptable (internal resources) both support an environment that values lifelong learning. Encouraged employees to learn new technologies and adapt to them better feel involved and satisfied in their positions, especially in the IT field where capabilities may soon get obsolete. Also, the study found there is insignificant effect (β = 0.075) of resilient workforce on employee engagement, therefore, rejecting H3 indicating that resilient workforce didn't predict employee engagement. The present study findings contradict with the prior studies (Beuren et al., 2022; Hudgins, 2016; Kašpárková et al., 2018). In the event that workers are routinely subjected to elevated stress levels, resilience may have undesirable consequences. Even resilient people can burn out over time, which can result in detachment. This study further found there may be other factors such as role ambiguity, lack of clear communication, poor rewards, poor work-life balance and the team dynamics affect the morale or may have low resilience among the workers. The variance of all factors was 68% in explaining employee engagement. Proactivity and adaptivity have almost same beta (39%) in influencing employee engagement. It is imperative for organisations to come up with an exhaustive plan for enhancing employee engagement, which takes into account not solely personal attributes such as resilience but also elements pertaining to interpersonal interaction, and supportive work environment. Sustained employee engagement is more likely to occur when positive environment and agile workforce are present.

HR professionals must employ technology to evaluate patterns and facts to gain insights that might be used to make key decisions on recruiting, minimizing attrition, driving improved productivity, and so on. Artificial Intelligence (AI) chatbots are the cutting-edge technology that agile HR is implementing to conduct sentiment analysis and take appropriate action in real time real-time to increase touchpoints with your employees is a wonderful way to explore your sources of engagement and disengagement. The study's findings urge business professionals to support an appropriate organizational learning and training culture and environment in their environment to foster agile behavior. The study suggested that the learning and training environment of an organization provide awareness, and autonomy as important values that can help in fostering a climate of continuous development of employees encouraging the workforce to be more agile in terms of attributes and behavior (Muduli, 2015). This study article makes a valuable contribution to the existing literature on employee engagement by explaining the dimension of workforce agility in the IT domain, an area that is becoming synonymous with multitudes in India today. These findings regarding the adaption of HR agility environment directly help and engage the employees for the long run. Further, the finding showed that every HR professional should be aware of these identified factors, and should bring them to the

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workplace to create engagement among the employees. Managers should focus on supporting the environment so that can manage their work-life in this new setting. Recommendations for the HR manager, employers should invest in well-being, provide various health insurance schemes, provide challenging tasks, virtual training, and upskilling, and frequently communicate to develop a team culture rather than a company culture.

Limitation and future research agenda

Even though several existing models provide a concise summary of the major characteristics that define an agile workforce, few of them seem to have a comprehensive definition. There is still a vagueness among human resource professionals about the skills that contribute to the advancement of distinct agile workforce characteristics. There is a need to maintain all the dynamic functions of the firm and that person should have an anticipation personality and should be resilient and quick to adapt the changes that are required by the business. Overall, there should be a flexible adaptive environment and empower the employees to participate in the decision-making activities of a firm. This study found resilience has no significant effect on employee engagement while the other two factors of workforce agility have significant effects. The study has certain shortcomings even though it adds a little to the theoretical and practical aspects of employee engagement.

First, as the data used in this study were cross-sectional, it is not conceivable to deduce a causal link from the findings. Future scholar can go for longitudinal studies, and also develop more robust theoretical framework showing mediating and moderating effects on employee engagement. Second, few studies have been talked about the empirical relation between factors of agility and its impact on organization financial and non-financial performance. Three are numerous factors of agile environment explored by Muduli and Choudhury, (2024), may be used for further empirical investigation Third, theoretically, it has been noticed that agile staff has improved organization performance. But practically there is a lot of factors (organization and employee related factors) that affect the organization's performance day by day. Fourth, the study's sample was limited to the Indian IT sector. Therefore, a replication of the study in various contexts and geographies with distinct respondent populations is necessary to establish a more rational foundation for the universality of findings.

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Exploring the Impact of Psychological Capital interventions on Employee Wellness: A literature review and conceptual framework

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Abstract

This study explores the complex relationship that exists between psychological capital interventions in industrial contexts and employee well-being. It synthesizes recent findings through an extensive literature review to identify trends, theoretical foundations, and empirical findings related to the intricate relationships between psychological capital and the general well-being of professionals in the field. Work-life balance, mental, physical, and job satisfaction are just a few of the dimensions of employee well-being that are explored in this study by identifying important concerns and information gaps. Our understanding is enhanced by the thorough literature assessment, which reveals plausible mechanisms impacting the effect of psychological capital interventions on wellness. This conceptual framework will be helpful to researchers and practitioners since it gives organizations strategic ways to strengthen psychological capital. In conclusion, this work significantly advances our knowledge of psychological capital and worker well-being, which will guide the next research and corporate initiatives to promote a strong and healthy workforce.

Introduction

The modern workplace is changing significantly with more challenges, demanding conditions, and an increased emphasis on employee well-being. To understand and enhance the overall well-being of industrial professionals there is a need to research psychological capital-focused therapy. This study focuses on an in-depth review to analyze the complex relationship between psychological capital solutions and enhancing the general well-being of industrial professionals through an extensive literature analysis and the development of a conceptual framework. The manufacturing sector has seen a dramatic transformation in recent years, which includes major technological advancements, organizational restructuring, and changing job roles. This has made situations more complex at work, which has brought attention to how important it is to prioritize employee well-being.

The manufacturing sector has seen a dramatic transformation in recent years, characterized by major technological advancements, organizational restructuring, and shifting job roles. The complexity that has caused in the workplace has highlighted how important it is to prioritize the welfare of your staff. Numerous studies have shown how intricate well-being is, encompassing psychological elements in

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addition to traditional metrics. Psychological capital comprises optimistic, resilient, hopeful, and self-assured psychological states. The mental, emotional, and physical health of an employee is known to be significantly influenced by these states (Luthans et al., 2007).

The primary objective of this research is to explore and understand how psychological capital treatments impact the well-being of industrial professionals. The study's objective is to include previous research by closely examining the literature to identify trends, theoretical foundations, and empirical findings that shed light on the intricate connection between psychological capital and worker well-being.

This work has significant implications for industry and academia. Organizations are beginning to recognize the importance of employee well-being for overall performance, retention, and productivity; for this reason, it is critical to understand how psychological capital interventions impact well-being. Practitioners, HR professionals, and organizational leaders can benefit from the knowledge gathered from this research by developing targeted interventions that enhance psychological capital and foster a stronger and healthier workforce.

Literature Review

In the modern workplace, employee well-being is increasingly recognized as a crucial element of success for both individuals and businesses. Psychological capital treatments are feasible strategies for enhancing well-being, which comprises multiple dimensions such as work-life balance, mental, physical, and job satisfaction. This review conducts a thorough literature evaluation to comprehend the intricate relationships between psychological capital treatments and these elements.

The employee well-being is recognized as a vital element of both individual and organizational success. Work-life balance, mental, physical, and job satisfaction are just a few of the dimensions of well-being that can be enhanced with psychological capital interventions. In this study, a thorough analysis of the literature is done to comprehend the intricate connections between psychological capital therapies and these elements.

Work-life balance, which is essential to employee wellbeing, is the harmony between demands in one's career and personal life. Several studies emphasize the significance of achieving and maintaining work-life balance to raise job satisfaction, lower stress levels, and improve overall employee wellness (Greenhaus & Allen, 2011).

Research evaluating the impact of psychological capital interventions on work-life balance has revealed a strong connection. Research has demonstrated that work-life balance can be enhanced by implementing strategies such as mindfulness training, flexible work arrangements, and supportive corporate cultures (Avey et al., 2011). After participating in these interventions, employees say they feel more confident in their ability to successfully manage work and personal commitments. These

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interventions also demonstrate positive effects on the delicate balance between work and personal life by increasing engagement and reducing burnout.

Employee mental health is an essential aspect of overall well-being that influences both personal productivity and organizational results. Psychological capital interventions are crucial for fostering good psychological states like optimism, self-efficacy, hope, and resilience. fostering psychological well-being (Luthans et al., 2006).

Studies exploring the relationship between psychological capital interventions and mental health frequently yield positive findings. Employees who have received interventions report having stronger coping strategies and resilience when presented with stressors at work (Avey et al., 2008). The cultivation of positive psychological states reduces anxiety and depression symptoms by equipping individuals with the ability to overcome challenges. Consequently, these therapies improve workers' mental toughness, which benefits workers' well-being and organizational productivity.

The relationship between psychological capital interventions is overlooked sometimes and physical health is a crucial aspect of worker well-being. Research indicates that these measures promote better lifestyles and lessen stress, both of which have an impact on physical health outcomes (Harter et al., 2010).

Job satisfaction, which is impacted by a variety of elements including corporate culture, leadership philosophies, and empowerment initiatives, is the primary determinant of employee well-being. Psychological capital interventions have a major impact on job satisfaction by promoting positive attitudes and behaviors among employees (Luthans & Youssef-Morgan, 2017).

There is no doubt that psychological capital treatments are associated with increased job satisfaction, according to empirical research. Interventions that prioritize positive leadership development and empowerment initiatives contribute to a more satisfying work environment (Dello Russo & Stoykova, 2015). Employees who feel they have opportunities for autonomy and decision-making as well as assistance for their personal development report higher levels of job satisfaction. Psychological capital therapies are crucial for fostering a joyful and engaging work environment, as evidenced by their positive effects on job satisfaction.

The current assessment of the literature shows the nuanced connections between many facets of employee well-being and psychological capital initiatives.

Companies might expect positive outcomes for the physical and mental well-being of their staff by

enhancing mental stamina. Resilience, improved coping mechanisms, and reduced stress are all associated with improved mental health outcomes. Additionally, adopting a better lifestyle has been connected to the good mental states that therapies cultivate, which are beneficial to physical health.

A positive correlation exists between increased psychological capital and elevated job satisfaction levels. Employees with high levels of optimism, hope, and self-efficacy are more likely to be satisfied

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with their jobs. Positive leadership development and empowerment initiatives create a supportive work environment, which increases job satisfaction even more.

The literature review revealed a consistent relationship between psychological capital interventions and improved work-life balance. Studies have consistently demonstrated positive outcomes, with therapies such as mindfulness training and flexible work schedules assisting individuals in striking a better work-life balance.

The effects of mental health and psychological capital interventions were found to be significantly positively correlated. Employees who received these interventions had improved resilience and coping mechanisms, which reduced stress and improved mental health overall.

Research gaps were discovered despite the wealth of data supporting the advantageous benefits of psychological capital interventions. There hasn't been much research done on these therapies' long-term effects and sustainability over time. Moreover, more study is needed to consider the unique contextual factors influencing the effectiveness of interventions in diverse industrial settings.

Following a comprehensive review of the literature, the study's findings were synthesized to produce a summary that both validated and extended prior knowledge regarding the impact of psychological capital treatments on employee well-being. Several studies that emphasize the significance of encouraging positive psychological states in workers are in line with the positive relationships that these interventions have with job satisfaction, mental, physical, and work-life balance (Avey et al., 2011; Luthans et al., 2006).

Studies that highlight how programs that develop leadership abilities, encourage a positive work atmosphere and empower people can lead to higher psychological capital are becoming more and more common.

According to findings, interventions that promote good psychological states at the individual and organizational levels are necessary to achieve desired goals. This lends support to the aforementioned hypotheses. In addition, the gaps in the research that have been identified support the need for additional detailed investigations, particularly about the long-term effects and contextual elements that influence the efficacy of interventions (Harter et al., 2010).

The findings demonstrate how crucial it is that companies support psychological capital projects as a pre-emptive step to enhance employee welfare. Organizations should integrate programs like mindfulness training, flexible work schedules, and positive leadership development into daily operations to create a comprehensive well-being plan.

Organizations need to realize how crucial leadership commitment is to the success of these interventions. Leaders need to foster a positive work atmosphere and actively participate in the psychological capital development of their teams. Creating an environment at work that promotes employee participation in decision-making will also boost the effectiveness of these treatments.

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This study practically suggests that businesses view well-being efforts as integral components of their business.

Conclusion and way forward

While the present study provides valuable insights, the next research can pursue several avenues to expand upon the understanding of psychological capital interventions and worker well-being. Longitudinal research is vital to study the long-term impact of interventions.

Understanding how these interventions impact well-being over time will provide important information on their long-term efficacy.

Examining potential applications of technology for psychological capital therapy delivery is another important area of research. In light of the increasing ubiquity of digital platforms and remote work, it is critical to understand how technology may facilitate the successful execution of these efforts.

Furthermore, a more complete picture of the unique experiences of the workers receiving these therapies can be provided by studies that mix qualitative and quantitative research approaches. Combining survey results with in-depth interviews or focus group discussions can aid in capturing the nuances of the impact on employee well-being.

The study's result contributes a nuanced perspective to the growing body of knowledge about psychological capital treatments and how they affect employees' well-being at work.

The findings demonstrate the positive relationships that these interventions have with work-life balance, mental and physical health, and job satisfaction. The study highlights how important it is to cultivate psychological capital through leadership training, empowerment programs, and positive workplace cultures.

These findings have practical applications for organizations that want to design and implement employee-focused programs that prioritize their well-being. Integrating such programs into business operations, as opposed to treating them as a stand-alone HR project, is consistent with the growing understanding of employee health as a strategic imperative.

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ISFT CS 34
IDENTIFYING FAKE REVIEWS THROUGH MACHINE LEARNING TECHNIQUES

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Abstract

Product reviews on e-commerce platform reflect customers' genuine experience with the platform's products. These reviews are a considerable factor in driving the revenue of an organization and in the generation of recommendations to the customers. However, the reviews often contain a mixture of fraudulent and actual reviews undermining the legitimacy of the businesses involved. As the customer purchase decision relies on the reviews provided by other customers, it becomes imperative to identify these fake reviews. Identification of fake reviews and their exclusion helps the customers to make an unbiased and informed purchase decision. Motivated by the performance of machine learning algorithms, this study aims to identify fake reviews through machine learning algorithms. Further, a comparison based on the performance of these algorithms has been provided to identify the best algorithm for detecting such falsified reviews. This identification and consequent exclusion of these fake reviews will help make the recommendation process unbiased.

Keywords

Fake review, e-commerce, feature engineering, machine learning, and recommender system

Introduction

Advent of Web 4.0 boosted online shopping of products through various e-commerce platforms such as Amazon, Flipkart, Myntra etc. Through these platforms, customers can provide their product or platform experience in the form of textual reviews. These customer reviews drive the sales of any business as they provide a genuine feedback of customer's experience with the business's products or services. These reviews exert considerable influence on fellow customer purchase decisions. However, the reviews provided by customers can be false representation of their experience with these products or services for different reasons. For instance, few businesses engage fraudsters to post falsified product reviews in order to promote their products or tarnish competitors' products [1]. The falsified reviews are posted with intent to mislead or confuse the other potential customers. In case of promotion of a product, several falsified positive reviews are posted by customers, who might not have even purchased or used them [1]. In case of demotion of a product, several falsified negative reviews are posted by customers to tarnish its image. Additionally, the reviews are sometimes also unrelated to the product for which it is being posted. This is done to advertise another product.

The above information makes it imperative to distinguish between falsified and genuine reviews

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as customer reviews or product reviews are a deciding factor in making a new purchase. As a part of this study, machine learning algorithms have been leveraged to identify fake reviews by treating the identification as binary classification problem [2].

Literature Review

Product reviews represent textual information about a customer's experience with a product. Apart from related product reviews, there also exist non reviews [3]. Non reviews can be majorly categorized as advertisements and unrelated reviews.

The large volumes of favorable reviews towards a product encourages customers to buy the products, hence increasing organizations' financial benefits, whilst unfavourable reviews may lead to not buying the products, returning the products and replacing the products, resulting in revenue loss [4]. Fake or spam reviews are any unwanted and irrelevant information about a product or service. Spammers post phony reviews regarding rivals' items and promote their own products [5].

The large number of unfavorable reviews is being generated through social media platforms. This makes it extraction of opinions and generation of reliable results complex [6]. In order to mitigate the adverse effects of fake review generation, supervision on the dependability of digital material on –ecommerce platforms is required. Several organizations engage people to post phony reviews in order to increase sales of their online products and services. These individuals are known as spammers, and the acts they engage in are referred to as review faking [7]. As a result, the presence of bogus and spam reviews heightens the importance of addressing the issue because they influence customers' and consumers' purchasing decisions. Fake reviews may be identified by considering them as classification problems in machine learning. The goal is to use machine learning algorithms to determine if the reviews are fraudulent or real [8]. Identification of fake reviews can be done by treating it as a classification problem in machine learning. The target is to classify the reviews as either fake or genuine by applying machine learning algorithms.

There are three categories of objectives for researching and identifying spam reviews: false reviews, false reviewers, and groups of fake reviewers [9]. However, because commercial websites have various ways for recognizing fraudulent reviews, identification is not revealed to the masses. These three approaches are as follows [10]:

- Review focussed- In this approach, based on the review content, identification of false reviews is done. The factors for identification include similarity of review content, usage of capitals in review text, usage of numbers, usage of brand names, the extent of relevance between item and review, usage of positive and negative phrases in the review [11].
- Reviewer focussed- In this approach, behaviour of the associated reviewers is taken into account [12], [13]. For this to work, all the relevant information about the users and their reviews are required. The factors considered in this include demographic features and other factors such as profile age, profile photo, number of reviews by the reviewer, maximum and average rating by the reviewer per day etc. [14]
- Product focussed- In this approach, the focus is on the product information. The features include sales count of the product, launch date of the product, number of purchases of the product, product price etc.

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As part of this study, review features have been focussed upon for their availability and genuine results.

Proposed Work

The proposed work carried out as part of this study, as shown in Figure 1 is explained as follows:

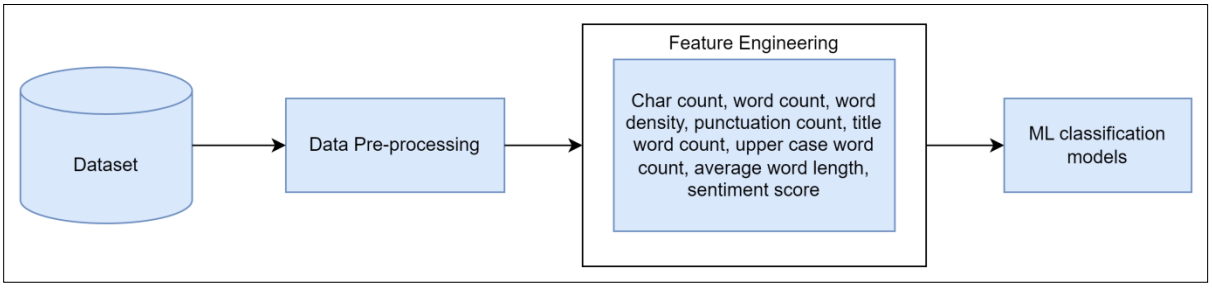


Fig. 1 Proposed work

Dataset

The dataset for this study has been sourced from https://osf.io/tyue9/ [15]. The dataset consists of ~20,000 original reviews - 'OR', i.e. written by the users and ~20,000 computer generated reviews - 'CG', through language models. This was done so as to get a corpus of labelled reviews of original as well as fake reviews. The snapshot of the dataset is shown in below Figure 1.

	category	rating	label	text_
2	Home_and	5	CG	Love this! Well made, sturdy, and very comfortable. I love it!Very pretty
3	Home_and	5	CG	love it, a great upgrade from the original. I've had mine for a couple of years
4	Home_and	5	CG	This pillow saved my back. I love the look and feel of this pillow.
5	Home_and	1	CG	Missing information on how to use it, but it is a great product for the price! I
6	Home_and	5	CG	Very nice set. Good quality. We have had the set for two months now and have not been
7	Home_and	3	CG	I WANTED DIFFERENT FLAVORS BUT THEY ARE NOT.
8	Home_and	5	CG	They are the perfect touch for me and the only thing I wish they had a little more space.
9	Home_and	3	CG	These done fit well and look great. I love the smoothness of the edges and the extra
10	Home_and	5	CG	Great big numbers & easy to read, the only thing I didn't like is the size of the
11	Home_and	5	CG	My son loves this comforter and it is very well made. We also have a baby
12	Home_and	5	CG	As advertised. 5th one I've had. The only problem is that it's not really a
13	Home_and	5	CG	Very handy for one of my kids and the tools are included in the package. I have one in
14	Home_and	5	CG	Did someone say, "Oriental for $60"? It is a great product for the
15	Home_and	1	CG	These are so flimsy! They are not the quality you would expect from a piece of furniture.
16	Home_and	5	CG	Makes may tea with out stirring. The only problem is that it's kind of hard to put
17	Home_and	5	CG	Absolutely adorable! And excellent price. We have had the wooden ones for a few months now and they
18	Home_and	5	CG	Love this! Perfect size for an entire family!Very good quality.
19	Home_and	5	CG	These look beautiful and so nice. The only problem is that it's not really a mesh one.
20	Home_and	5	CG	Exactly what you would expect. I love the look and feel of this pillow.
21	Home_and	5	CG	10 Stars, I would highly recommend this item. We love this blanket.
22	Home_and	5	CG	Great little egg masher. We have had it for a few months now and it's been
23	Home_and	5	CG	As advertised. Easy to use. Love the colors. Also, the dimensions are just
24	Home_and	5	CG	it is exactly as pictured. I love the look and feel of this pillow.

fake reviews dataset

Fig. 2 Snapshot of the dataset

Data pre-processing

Data Pre-processing refers to processing of data in a manner suitable for the required application. In this study, the target type of this dataset is the label column that is to identify if the review is computer generated or original review. The imputation method used for imputing missing values used in this study is simple imputation wherein, mean values are imputed for numeric imputation and mode values are imputed for categorical imputation. Stratified k fold method is used for validation with fold number set as 10.

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Feature engineering

Feature engineering refers to identifying features of use from the given dataset. The following features have been extracted from the review text using Natural Language Processing techniques in Python:

i. Char count:
ii. Word count
iii. Word density
iv. Punctuation count
v. Title word count
vi. Upper case word count
vii. Average word length
viii. Sentiment score

For instance, for the following review text, *'Love this! Well made, sturdy, and very comfortable. I love it!Very pretty'*, the char count is 75 (with spaces), word count is 12, word density is 5.77, punctuation count is 5, title word count is 3, upper case word count is 1, average word length is 5.17 and sentiment score is 0.9592.

Machine Learning classification models

The extracted features serve as an input to the machine learning models namely, Light Gradient boosting machine, Extreme Gradient Boosting Machine, Random Forest, Gradient Boosting and AdaBoost [16], [17]. The train test split ratio has been kept as 0.6 and 0.7 to compare the performance of the said models. For assessing the performance, widely used parameters such as, accuracy, precision, recall and F1 score have been used. Additionally training time of the algorithms has also been used to compare the performance.

Result and Conclusion

The result of the performance of machine learning algorithms is shown in Table 1. Ensemble learning models in machine learning have been used to identify fake reviews and original reviews [18]. Four boosting models and one bagging model have been compared and contrasted for performance. When training size is set as 0.6, Light Gradient Boosting machine performs the best with an accuracy of 0.7596, precision of 0.7598, recall of 0.7596, f1-score of 0.7595 whereas AdaBoost performs the worst with an accuracy of 0.7357, precision of 0.7361, recall of 0.7357 and f1-score of 0.7356. When the training size is set as 0.7, Extreme Gradient Boosting machine performs the best with an accuracy of 0.7604, precision of 0.7607, recall of 0.7604 and f1-score of 0.7603 whereas AdaBoost performs the worst with an accuracy of 0.7361, precision of 0.7363, recall of 0.7361 and f1-score of 0.736. The good performance of Light Gradient Boosting machine and Extreme Gradient Boosting machine can be attributed to the fact that it uses a regularization function in it.

Table 1 Performance of ML models

	Train Size=0.6					Train Size=0.7				
ML Model	**Accuracy**	**Precision**	**Recall**	**F1-Score**	**TT(sec)**	**Accuracy**	**Precision**	**Recall**	**F1-Score**	**TT(sec)**
Light Gradien	0.7596	0.7598	0.7596	0.7595	1.3756	0.7591	0.7596	0.7591	0.7589	1.637

t Boosting Machine										
Extreme Gradient Boost	0.7587	0.7589	0.7587	0.7586	0.584	0.7604	0.7607	0.7604	0.7603	0.805
Random Forest	0.7507	0.7509	0.7507	0.7507	4.355	0.752	0.7523	0.752	0.7519	5.755
Gradient Boosting	0.7449	0.745	0.7449	0.7449	4.207	0.7444	0.7445	0.7444	0.7444	4.708
AdaBoost	0.7357	0.7361	0.7357	0.7356	1.379	0.7361	0.7363	0.7361	0.736	2.366

To summarise, identification of fake reviews is a vital task for the customers in order to arrive at an unbiased purchase decision. It is essential from the side of e-commerce platforms to prevent unnecessary fluctuation of organization's revenue and profits. This identification can be done through the help of machine learning algorithms by treating the target as a binary classification problem. Bagging and boosting are major categories of ensemble learning in machine learning with improved performances as compared to the traditional machine learning algorithms. Two ensemble learning models namely light gradient boosting machine and extreme gradient boosting machine perform the best when the training size is set to 0.6 and 0.7 respectively. As part of the future work, the identified fake reviews can be excluded from the recommendation process and then the performance of recommendation algorithms be evaluated to check for improvements.

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ISFT CS 146
Game Theory: Challenges and Issues

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Abstract

Game theory, a fundamental framework for analyzing strategic interactions among rational decision-makers, is widely utilized in diverse academic fields such as economics, political science, biology, and computer science. This summary underscores the significant challenges researchers confront, acknowledging the field's inherent dynamic complexities. A notable challenge arises from the presumption of perfect rationality in traditional game theory models. The evolution of human decision-making, influenced by psychological factors and social dynamics, has led to behavioral game theory, which integrates psychological insights to model deviations from strict rationality. The issue of incomplete information presents a substantial obstacle, as players often lack comprehensive knowledge about the game or the strategies employed by others. Cooperative game theory introduces challenges related to forming coalitions, ensuring stability, and equitably distributing gains among participants. Examining repeated game interactions reveals challenges in sustaining cooperation over time. The integration of artificial intelligence (AI) complicates the landscape of game theory, raising ethical considerations regarding algorithmic decision-makers. Addressing biases, transparency, and unintended consequences becomes imperative for the responsible deployment of AI in strategic contexts. The interdisciplinary nature of game theory necessitates collaboration between theoretical models and practical applications. Bridging gaps across diverse fields is essential for enhancing the real-world effectiveness of game theory and fostering its continual evolution. In summary, this concise overview highlights the challenges in game theory, emphasizing its dynamic nature and sustained relevance in comprehending and shaping strategic interactions across various disciplines.

Keywords
Game Theory, Decision-making, Rationality, Incomplete information, Challenges and Issues.

Introduction

Game theory is a branch of applied mathematics that provides the tool to analyze the strategic interaction between different players (called agents) and depending upon the strategy of the player, action is determined. The concept of game theory was developed by John Von Neumann in 1928 by giving the “Minimax Theory”[1]. Later in the 1940s and 1950s mathematicians and economists like John Nash, Oskar Morgenstern, and Lloyd Shapley do further works[2-4] on the non-cooperative game and give the concept of “Nash Equilibrium”. For this recommendable

work, John Nash won the Nobel Prize in Economics in 1994. Game theory can be divided into two main categories: Cooperative game and Non-Cooperative game. In a cooperative game, players can form coalitions due to external enforcement of cooperative behavior and competition and finally the payoff will be distributed among these players according to their contribution in a fair manner while in non-cooperating game participants act independently and selfishly in an effort to maximize their own utility function

Over time, game theory has been applied in many different areas including economics, political science, finance, biology, psychology, and computer science, and significant work is done in the development of game theory like prisoner's dilemma, Evolutionary game theory, Behavioral game theory, Algorithm game theory, mechanism design theory, Auction theory, and voting theory. Overall game theory is a versatile tool have their application in different areas like project management [9, 11-14, 20], computer network management [6, 18], finance management [5], and economics [7, 15-17, 19] etc.

Literature Review

Before discussing the challenges and issue, let us take a look on the various contributions made in this research area by the various explorers and researchers. In this section, we take some research papers which have used game theory to solve different problems related to real-life scenarios.

He et al. [3] in his work has designed a game theory-based model to solve the problem of energy crisis. The system involves all the players (stakeholders) of the energy system i.e. the supply side (generation), the distribution network (planning and dispatch), and the demand side (consumers). All these players have participated in a competitive environment which has been simulated through cooperated games, non-cooperated games, and Stackelberg game theory. The paper concludes that the problems can be best solved through a mixed game theory environment which is a hybrid of the above mention game theories. The major problem with the paper is hybridization which is quite a complex process and may vary from one domain to the others.

Martin et al. [4]have proposed a game theory-based model to solve multi-robot task allocation (MRTA) problem. The In this, average marginal contribution is calculated through shapley value which divide the initial MRTA problem into further sub-problems, using ranking and clustering robots. A simulation case study shows the benefit of proposed study considering the genetic algorithm (GA) as the baseline study.

Mamoudan et al. [5]Proposed a theory with the fusion of machine learning and game theory to predict the price of food products. Using the combination of machine learning technique like ANN, CNN, LSTM, and GA (genetic algorithm) optimized model is proposed which determine the price of the competitor product. Then this model is merged with the game theory model which will predict the price of perishable food.

Deng et al. [6] proposed an NVAS Scheme(non-interactively verifiable privacy-preserving FL model aggregation scheme)during COVID-19 by considering the game theory-based security model of FL(federated learning).this scheme used homomorphic secret sharing scheme which ensures that private data of users can't be leaked by a malicious server. Through the verification algorithm and a cuckoo filter, it was found that the NVAS scheme works much better than any

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other traditional method in a wireless communication environment.

Zhou et al. [7]Proposed a game theory-based data fusion method that navigates the ship's position in real-time. For designing a game strategy they consider model-driven discrete-time Kalman fusion, and a data-driven adaptive weighted fusion, based on these game objects local estimation is converted into the final fusion result. Extensive simulation and model experiments support the accuracy and fault tolerance capacity of this proposed method.

Moafi et al. [8] Proposed a model based on cooperative game theory and blockchain technology in trading of renewable energy which can maximize the user's profit. A modified version of Proof of Energy Generation (PoEG) and based on this PoEG protocol a coalition formation algorithm is developed. Through comprehensive theoretical analysis and simulation experiments, the system is validated on the real-life dataset and the result shows that user get benefited by 6.5% in terms of energy saving as compared to baseline model.

Chen et al. [9]Designed a distributed energy trading scheme based on game theory and consortium blockchain peer-to-peer peer platform is constructed for direct transaction which is secured by cryptographic technique such as hash key and digital signature associated with blockchain. Through though game theory model an energy transaction matching mechanism is designed in which an equilibrium solving algorithm is used which cause the maximization of profit among all the participant in energy trading. The experimental result shows that this scheme is highly secure in distributed energy transaction scenarios.

Li et al. [10] proposed methodology which mitigate the risk management in urban natural gas pipelines. First, the involvement proportion of stakeholders in risk management is estimated by static game theory which is further converted into dynamic evaluation games which exactly optimizes the strategy for risk management.

Wei et al. [11]proposed a multi-objective migrating birds optimization algorithm based on game theory to solve the problem of dynamic flexible job shop scheduling. Game theory balances Pareto optimality and fairness between production efficiency and stability and approximate Nash equilibrium is designed. A multi-objective replacement solution is designed while concerning the attribute of the problem. Through experiment, it is validated that this algorithm performed well while comparing another advanced algorithm.

Seyyed et al. [12]Developed an evolutionary game theory-based model which manages grain production to reduce global warming considering the financial and time constraint. This model considers the strategy of the producer of Iran toward sustainability and using the SimaPro 8.0.3 software impact of renewable and non-renewable electrical sources on global warming is found out during the life cycle of grain production. It was found that by using biomass as an electricity source global warming can be reduced from 269 kg CO2-eq to 18 kg CO2-eq.

Ullah et al. [13]Use various game theory mathematical models to know about irrationality in investors' behavior due to stress and loss aversion behavior of investors and find out the way to deal with this behavior. A qualitative dataset is used by collecting the sample of 16 experienced stock investors from Pakistan and the USA. Various game theory like Bfounded Rationality Theory, Prospect theory, Theory of Mind, The ABC (Activating–Beliefs–Consequences) model, and the Dual System Model of preference is used to find the irrational nature of investor and it had been concluded that the biased nature of investor, lack of awareness about the market situation and overconfidence cause this kind of problem.

Wei et al. [14]proposed an adversarial game neural network model based on LSTM and predict

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the stock ranking .this model also combined the trading task to construct an MS-WRSE loss function that considers the stock ranking to optimize the network. The adversarial game neural network architecture is designed for interactive training of two neural networks, the Main neural network and the Auxiliary neural network with different inputs and finally reaching the equilibrium state. The result of the adversarial game network compared with the classical time series model and it was found that it better eliminate the effect of market-style-factor on stock ranking prediction.

Duan et al.[15]used cooperative game theory along with dynamic modelling and control theory to solve the problem of optimal resource allocation system for technology innovation ecosystem and find an optimal balance between control input and system performance.

Youssefi et al.[16]proposed an energy management strategy for smart building with fuel cell and battery hybrid energy storage (FBHES) using Max-Min game theory. Particle swarm optimization (PSO) algorithm calculates the optimal power distribution strategy to deal with the worst possible demand power in the framework of the max-min game model. Simulation results show that the degradation of the Fuel cell is 12.64% lower than the traditional Game theory and lifetime of the battery is increased by 23.16% and 82.81% compared with mixed-integer linear programming EMS and rule-based strategy.

Challenges and Issues

Based on the above literature, there are several contributions made by various researchers in using game theory to solve real-life problems. However, there are also some challenges and issues highlighted in these studies. Here are the challenges and issues based on the literature:

Table 1. Game Theory Challenges and Issues in above literature

Paper	Problem Addressed	Game Theory Approach	Challenges/Issues
He et al. [3]	Energy Crisis	Hybridization of cooperative, non-cooperative, and Stackelberg games	Complexity of hybridization, domain-specific variations
Martin et al. [4]	Multi-Robot Task Allocation (MRTA)	Cooperative game model using Shapley value and sub-problems	Complexity in cooperative game model implementation
Mamoudan et al. [5]	Predicting Food Product Prices	Fusion of machine learning (ANN, CNN, LSTM, GA) and game theory	Integration challenges, effectiveness across different domains
Deng et al. [6]	Privacy-Preserving FL during COVID-19	Game theory-based security model for federated learning	Implementation during critical periods, validation of privacy-preserving models

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Zhou et al. [7]	Ship's Position Navigation	Game theory-based data fusion method	Ensuring accuracy and fault tolerance in real-time navigation
Moafi et al. [8]	Cooperative Energy Trading	Game theory and blockchain technology	Scalability, security, and real-world applicability
Chen et al. [9]	Distributed Energy Trading	Game theory-based energy transaction matching mechanism	Security concerns, effectiveness of equilibrium-solving algorithm
Li et al. [10]	Risk Management in Urban Natural Gas Pipelines	Static and dynamic game theory for risk management	Integrating dynamic evaluation games, stakeholder involvement
Wei et al. [11]	Dynamic Flexible Job Shop Scheduling	Game theory-based multi-objective migrating birds optimization	Achieving Pareto optimality, fairness, and Nash equilibrium in dynamic scheduling
Seyyed et al. [12]	Grain Production for Global Warming Reduction	Evolutionary game theory for grain production	Financial and time constraints, impact of renewable and non-renewable electrical sources on global warming
Ullah et al. [13]	Irrational Investor Behavior	Various game theories for understanding investor behaviour	Addressing biases, lack of market awareness, and overconfidence
Wei et al. [14]	Adversarial Game Neural Network for Stock Ranking	LSTM-based adversarial game neural network	Effectiveness in eliminating market-style-factor effects on stock ranking prediction
Duan et al. [15]	Optimal Resource Allocation in Technology Innovation Ecosystem	Cooperative game theory, dynamic modeling, and control theory	Balancing control input and system performance in a dynamic innovation ecosystem

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Youssefi et al. [16]	Energy Management in Smart Buildings	Max-Min game theory for fuel cell and battery hybrid energy storage	Addressing degradation concerns in fuel cells, optimizing battery lifetime compared to other strategies

This table summarizes the key aspects of each research paper, including the addressed problem, the game theory approach used, and the associated challenges or issues. below we discuss these challenges and how to resolve them.

Discussion

The application of game theory to real-world scenarios introduces a set of intricate challenges and issues that demand thoughtful consideration from researchers and practitioners. One primary challenge lies in the complex hybridization of various game theories, necessitating the development of standardized methodologies and frameworks to streamline the integration process. Achieving a cohesive and standardized approach is particularly challenging due to the inherent complexities of different application domains. Researchers must strive to create guidelines and best practices that not only simplify the hybridization process but also ensure its adaptability across diverse contexts.

Computational intensity poses another significant challenge, especially when dealing with game theory models in scenarios involving multiple strategic interactions. As the number of players increases, so does the complexity of calculations, making it essential to strategically leverage advanced computational capabilities and explore optimization techniques. This approach is vital for ensuring the efficiency of game theory models in handling the intricacies of real-world strategic interactions.

The integration of game theory with other disciplines, such as machine learning or blockchain, presents yet another obstacle due to differing terminologies, assumptions, and objectives. Bridging these interdisciplinary gaps requires collaborative efforts and effective communication among experts from diverse fields. Establishing common terminologies and fostering interdisciplinary collaboration are pivotal steps toward enhancing the integration of game theory with other methodologies.

Privacy and security concerns emerge prominently in applications like privacy-preserving federated learning, where the protection of sensitive data is paramount. Continuous improvements in cryptographic techniques and collaboration with cybersecurity experts become imperative to enhance the privacy-preserving capabilities of game theory models. Ensuring the real-world applicability of these models involves rigorous simulations, experiments, and collaboration with industry stakeholders. These efforts are essential to validate the models and enhance their relevance across diverse contexts.

Behavioural assumptions inherent in game theory models, which often rely on the premise of rational decision-making, present challenges when applied to the complexities of human behaviour. Combining game theory with insights from behavioural economics or integrating learning mechanisms becomes crucial to enhance the accuracy and applicability of these models. By acknowledging and addressing behavioural nuances, researchers can refine game theory models to better align with real-world decision-making processes.

Regulatory and ethical considerations come to the forefront, especially in applications like

blockchain-based trading, where compliance with existing regulations and ethical standards is imperative. Collaboration with policymakers, adherence to regulatory frameworks, and a commitment to ethical practices are essential components of implementing game theory models responsibly. Ensuring a fair and equitable distribution of benefits further solidifies the ethical foundation of these applications.

Finally, the dynamic nature of real-world environments poses a challenge to the adaptability of game theory models. Developing adaptive strategies and dynamic optimization algorithms is crucial to ensuring the continued effectiveness of these models in environments characterized by constant change. Continuous refinement based on real-time data and iterative model updates become essential components of navigating the complexities of dynamic scenarios.

Conclusion

In conclusion, addressing these challenges demands a comprehensive and collaborative approach from researchers and practitioners. The successful application of game theory to real-world complexities requires the integration of advancements in technology, methodological innovation, and interdisciplinary collaboration. By remaining responsive to evolving demands and refining models iteratively, the field of game theory can continue to contribute effectively to solving complex problems across diverse domains.

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ISFT EE 04
ANALYSIS OF MINIATURIZATION TECHNIQUES OF IMPLANTABLE ANTENNA

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Abstract
Implantable antenna is boon to medical field as it provides the way to control the electronic medical devices and provide the command to the circuit which is implanted in human being body for its proper functionality. In designing of these implanted antennas, its compatibility with human body tissues are also taken into consideration. By making it possible to monitor and treat patients with a variety of medical diseases more effectively and minimally invasively, implantable antennas have completely changed the world of medical technology. Implanted antennas are the new era in of patch antenna where antenna in miniaturized form implanted on human body for controlling the electronic device inside the human being. In this paper the effect of miniaturization techniques of patch antenna and its effects on parametric antenna properties such as return loss, radiation efficiency, bandwidth and gain are explored.

Keywords
Implantable antenna, Dielectric constant, Resonating frequency, Antenna-gain, Return loss, Voltage standing wave ratio.

Introduction
Medical devices implanted in humans are a blessing. These devices are intended for internal patient insertion and have a broad variety of diagnostic and therapeutic applications. Implanted medical devices include defibrillators, pacemakers, glucose monitors, arterial pressure monitors, and medicine fusion pumps. The area of healthcare has benefited greatly from implanted medical devices, which provide patients with a range of diagnostic and therapeutic advantages. With a variety of functions to monitor, treat, or help with various medical diseases, these devices are made to be implanted into the human body. These devices are implanted inside the human body so they are termed as implanted electronics devices and controlling these devices required a proper wireless communication system. Wireless communications can be categorized in three modes –The first mode is Radio frequency communication, second mode is microwave communication like LOS of long range upto 90 Km using directional microwave antenna and third mode is infra red based communication of short range home entertainment devices like remote controls etc. The use of micro strip patch antennas is from daily use appliances like-mobile, television, wireless personal area network to medical sciences in different life supporting electronics devices, industrial application in smart sensors devices in automobile and autonomous robot is estimated using a variety of miniaturization methodologies. For implanted devices the fabricated antenna are used and they are termed as patch antenna. The first design of fabricating antenna in patch form on devices was first proposed in 1953 [1]. Patent of designing of patch was first applied in 1955 [2]. Investigation of different dielectric materials substrate parameters and weight reduction techniques by using different substrates materials was

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explained in detail for satellite applications [3-4]. Broadband designing of triangle shape microstrip patch antenna and its operation in dual frequency band application [5]. Microstrip-patch antenna designing and its practical working for frequency of 5 to 6 GHz applications [6]. Radiation characteristics of microstrip antenna for different substrate size elaborated in detail [7]. Patch antenna have wider application, it is in use of daily life all the wireless communication or satellite communication applications are based on these types of antenna [8, 9].The use of micro strip patch antennas is not only limited to daily use appliances like- mobile, television, wireless personal area network but have a wide applications in medical sciences in different life supporting electronics devices.

Diagnostic capabilities, therapeutic interventions, enhanced quality of life, precision medicine, remote monitoring, and long-term durability are benefits of implanted medical devices. Antennas used in implanted medical devices are microstrip patch antenna and they are fabricated antenna where different structure of patch is mounted on dielectric substrate by different techniques used for fabrication. For fundamental understanding the concept of patch antenna - rectangular structure is shown in figure 1. Patch antenna is basically a highly conducting material like gold, silver or copper etc.

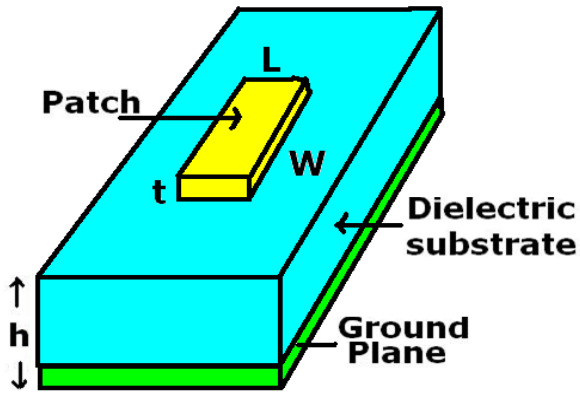


Fig.1. Microstrip-patch antenna of rectangular dimension

Optimization Methods

Designing of antenna using patch fabrication techniques already miniaturized the bulky design of antenna, the basic design concept of patch design is shown in figure 1. As our requirement is small size fabricated antenna so as according to the requirement in medical application, different antenna design and its miniaturization techniques can be used to minimize the microstrip patch antenna. In designing of implantable antenna few suggestive techniques of patch antenna miniaturization are proposed as-

1. Applying different shapes of patch and improving its electrical size or current path.
2. Altering the substrate's material to reduce the wavelength in the substrate layer.
3. Current path lengthening.
4. Shorting and folding.
5. Inductive or capacitive loading.

Proposed Patch Design

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A. Design Method 1: Different shapes of patch

Using optimized shape of patch as per application- Changing the shape of antenna such that the electrical size or current path is increased. For designing of patch antenna with optimum result, figure 2 shows some common shapes of patch antenna.

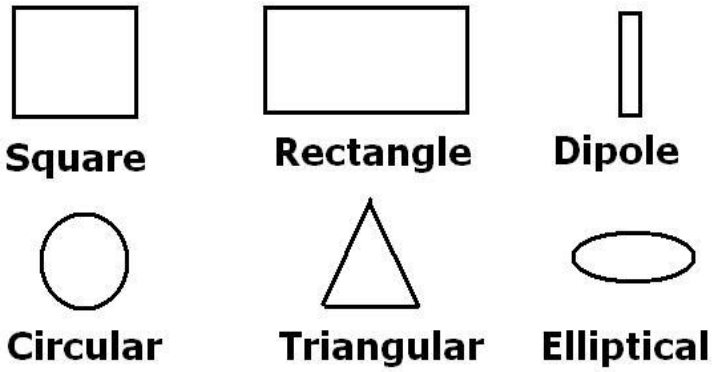


Fig.2. Possible dimensions of microstrip patch antenna

Additionally, the patch's shape can be changed to an H- shape, T-shape, I- shape, E shape, U-shape etc. [10]. E-shaped patch has previously established its significance in the field of antenna design [11, 12]. As E-shaped antenna have wide range of wireless application in 4 – 6 GHz [13, 14]. Rectangular patch is modified in the shape of English alphabet 'E' and the geometry is shown in figure 3.

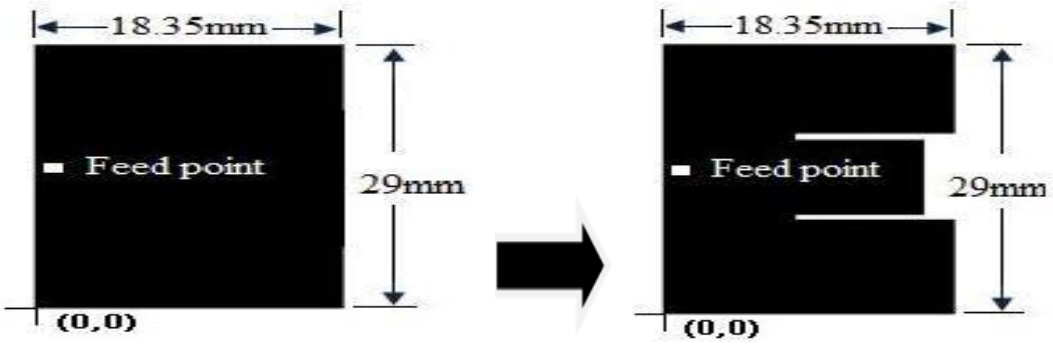


Fig.3. Modified E shape patch antenna

Design Method 1 Simulated Output:

For designing of modified patch antenna following parameters are computed using the formula suggested by C. A. Balanis [15].

Operating frequency fr = 5.8 GHz
Dielectric constant ε_r = 2.2
Height of patch h = 1.5875
E shaped microstrip patch antenna equivalent circuit is shown in figure 4-

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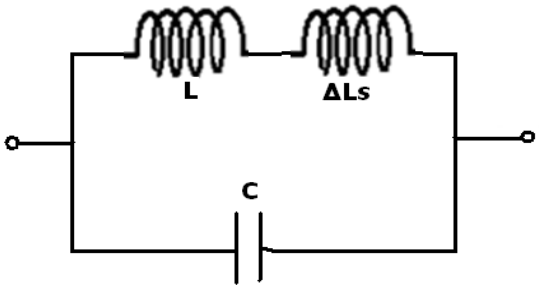


Fig.4. Equivalent circuit of proposed modified E shape patch antenna

Figure 5 depicts the return loss obtained on simulation of an E-shaped patch antenna using the electromagnetic simulator IE3D.

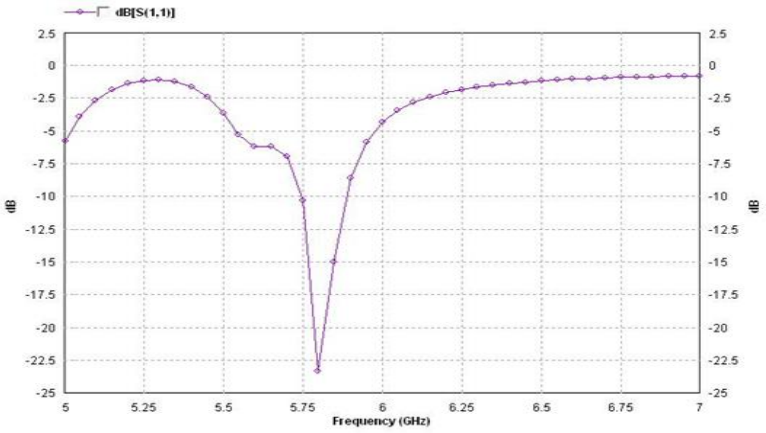
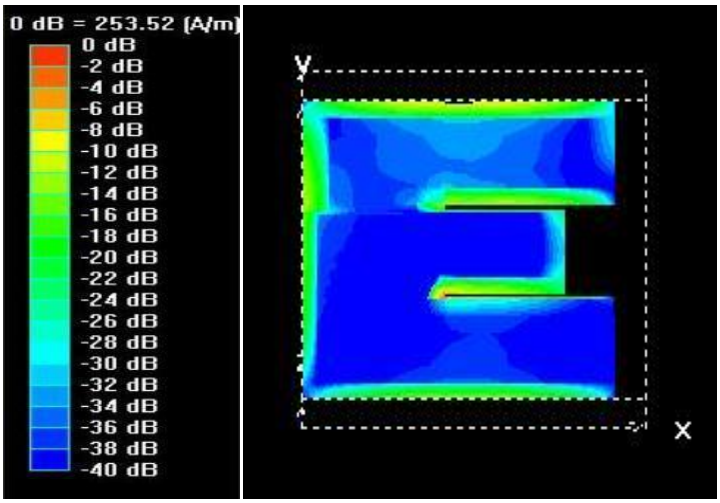


Fig.5. Return loss of proposed modified E shape patch antenna

Return loss of -23.3053 dB is achieved on modifying the electrical size or current path and also 150 MHz of bandwidth was attained at the desired 5.8 GHz resonant frequency.

The current distribution of modified patch antenna is shown in figure 6.



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Fig.6. Current distribution of proposed modified patch antenna

Current is uniformly distributed in E shape antenna and it shows that designed microstrip patch antenna dimension is uniform for field distribution. Electromagnetic scale is also shown in figure 6 for current intensity at different position on E shape patch antenna.

B. Design Method 2: Altering the substrate's material

Using different substrate material as according to the antenna application requirement –

By changing the substrate layer of the patch antenna to a new material with a dielectric constant of range from 2 to 12 (2 < ∈r <12). For designing of patch antenna substrate materials of different dielectric constant having range from 2 to 12 are considered consider for patch antenna design [16].

The substrate can be categorized as-

1. Dielectric constant more than 1 and less than 2: Foam, air and polystyrene etc.
2. Dielectric constant more than 2 and less than 4: Reinforced Teflon, fiberglass etc.
3. Dielectric constant more than 4 and less than 10: Quartz, ceramic or alumina.

A relation between the patch antenna dimension i.e, length - width and dielectric permittivity εr is

$$W = \frac{1}{2f_r\sqrt{\mu_0\,\epsilon_0}}\sqrt{\frac{2}{\epsilon_r + 1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}$$

Length-

$$L_{eff} = L + 2\Delta L$$

where,

$$\Delta L = 0.412h\,\frac{(\epsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\epsilon_{reff} + 0.258)(\frac{W}{h} + 0.8)}$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} - \frac{\epsilon_r - 1}{2}\,[1 + 12\,\frac{h}{w}]^{-1/2}$$

These equations are used for finalizing the dimensions of patch antenna design on the simulator.

Design Method 2 Simulated Output:

Rectangular patch antenna is designed and simulated on electromagnetic simulator IE3D for different dielectric substrate.

Parameter 1: Return Loss

Return loss for three selected dielectric material based patch antenna of same dimension is simulated on simulator and output is shown in table 1.

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Table1. Return loss of selected substrates material for patch antenna design

Substrate Materials	Return Loss (dB)
RT Duroid	-24.04
RO4003	-22.26
FR4	-20.64

Return loss obtained on simulating the patch antenna design using different substrate material are shown in figure 7. Simulated output shows that RT Duroid has better performance and radiation in comparison to other materials.

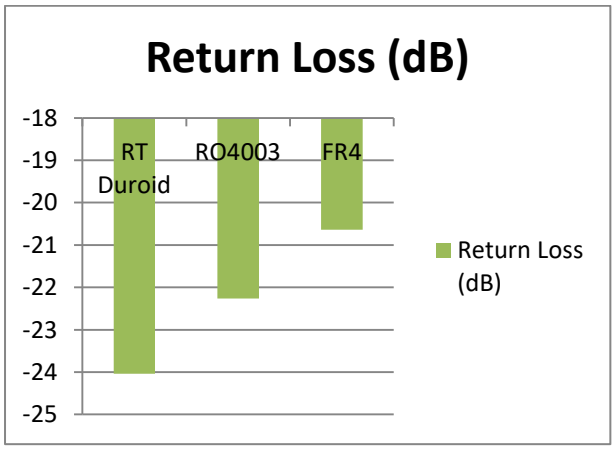


Fig.7. Return loss comparison of selected substrates material for patch antenna design

Parameter 2: Voltage Standing Wave Ratio

VSWR for three selected dielectric material based patch antenna of same dimension is simulated on simulator and output is shown in table 2.

Table2. VSWR of selected substrates material for patch antenna design

Substrate Materials	VSWR
RT Duroid	1.26
RO4003	1.68
FR4	1.28

Output VSWR is approximately equal to 1 which is one of basic requirement for practical designing of patch antenna. VSWR of the patch antenna design using different substrate material are shown in figure 8.

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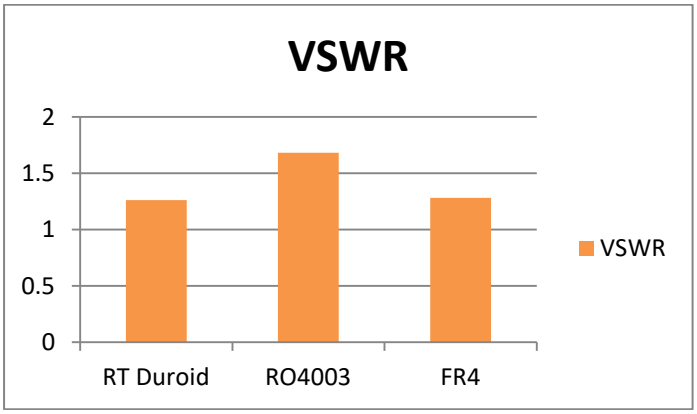


Fig.8. VSWR comparison of selected substrates material for patch antenna design

Parameter 3: Gain

Gain of proposed design patch antenna using three selected dielectric material of same dimension on simulating on IE3D electromagnetic simulator is shown in table 3.

Table 3. Gain comparison of selected substrates material for patch antenna design

Substrate Materials	Gain (dB)
RT Duroid	3.42
RO4003	5.2
FR4	1.89

Graphical comparison of obtained gain of different material based patch antenna is shown in figure 9. The output gain satisfies the conditions required for designing the suggested patch model practically.

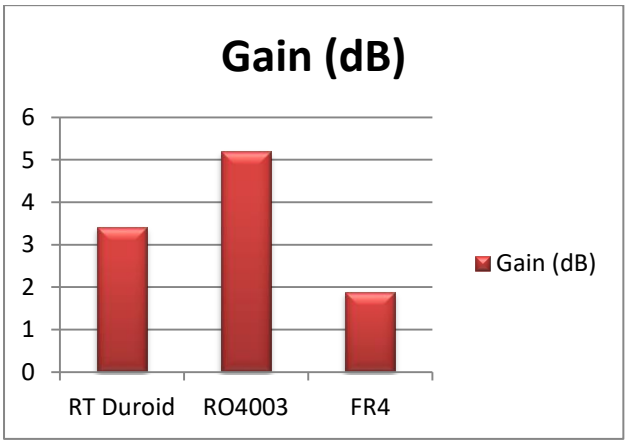


Fig.9. Gain comparison of selected substrates material for patch antenna design

C. Design Method 3: Current path lengthening

The current path lengthening is also used to miniaturize an antenna. The implanted antenna's

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resonance frequency shifts to a lower range as the current path lengthens. This can be accomplished by altering the patch shape or adding slots to the patch, introducing meander lines, spiral structure etc. In the fig. 10, mender line structure and spiral structure are also shown for lengthening of current path.

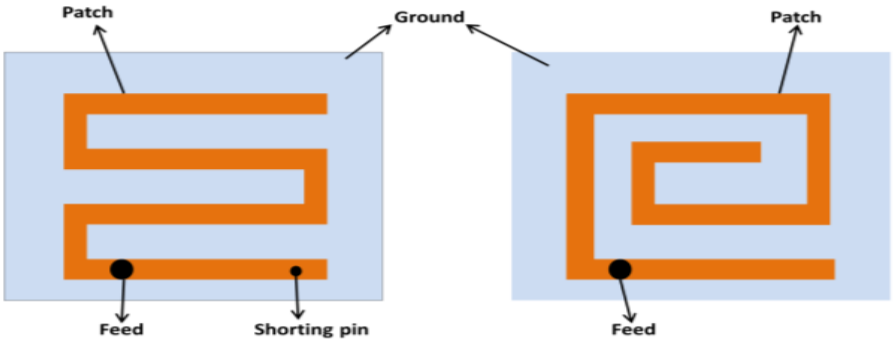


Fig.10. Mender line and Spiral structure

Some fractal geometries are also used to generate efficient miniaturized antennas. Actually, these are the space filling shapes that allow electrically large features to be obtained into a compact region while lowering bandwidth. The ohmic losses developed in such an antenna are larger and these losses results in decreased radiation efficiency.

A layer of conductors separated by laminations is also utilized to address this issue. It uses a conductor separated by laminations that helps in improving the gain and efficiency. This technique is called Patch stacking or Radiator stacking. It is also demonstrated that antenna gain is improved with increase in conductor layers thus improving the efficiency. When used a 5-layer conductor instead of single-layer conductor, efficiency of the new antenna is improved by 30%. In the literature, several papers have been published where size of antenna is lowered by inserting various slots into the antenna. But when this approach is used, the polarization purity is usually low.

D. Design Method 4: Shorting and folding

To reduce their size and make them electrically small, patch antennas are folded and shorting pins are being used. The Planar Inverted F Antenna (PIFA) structure, thus obtained by folding is the simplest technique to miniaturize implantable antennas. The PIFA's wavelength is a quarter of its resonant length (λ/4). Hence, when size reduction is required, PIFAs are used commonly over microstrip patch antennas. A λ/4 wavelength antenna has the same Q as λ/2 wavelength equivalent i.e. a simple patch antenna, according to a theoretical study. However, because the antenna aperture has decreased, the antenna directivity has reduced as well, impacting the antenna gain directly. Folding and shorting can thus be used to miniaturize MPA. As in, the antenna miniaturization is done by using folded slot for ISM band operation. A similar structure of the folded antenna is also shown in fig.11.

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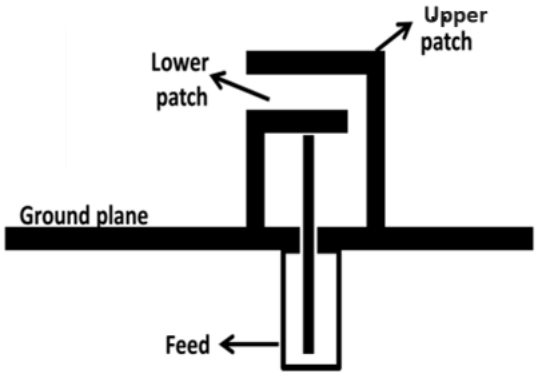


Fig.11. Folded Antenna

This method, however, comes with a cost: the antenna's gain and directivity are reduced. Additionally, this approach can occasionally make the MPA's geometry more complicated and non-planar, increasing the structure's complexity and compliance. When used correctly, however, this strategy has little influence on the antenna's effectiveness.

E. Design Method 4: Inductive or capacitive loading

The designed antenna may or may not be perfectly resonant antenna. The impedance may be perfectly matched or not i.e. there may be capacitive or inductive part also in the antenna impedance. Hence, to remove the capacitive or inductive effects, loading techniques are used. Depending on the kind of reactance, these loading techniques may be capacitive or inductive, thus minimizing the imaginary component of the impedance thus providing good impedance matching and so contributing in size reduction. In, the inductive loading approach was applied. The capacitive loading approach is employed in for size reduction of the object. The antenna's size may be reduced by 72% when inductive/capacitive loading is used.

Conclusion

Detailed analysis of miniaturization of implantable patch antenna design used for medical devices and its simulated output are shown in this paper. Proposed and designed techniques i.e, altering of the shapes of patch, altering of the dielectric material, current path lengthening, shorting and folding and inductive or capacitive loading are the different approaches that can be used for optimizing the features of patch antenna so that it can be used as implantable antenna. Designing parameters like - simple or complex design geometry and its compatibility with human body tissues are also taken into consideration.

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A REVIEW ON CLUSTERING ROUTING APPROACH FOR ENERGY EFFICIENT WIRELESS SENSOR NETWORKS

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Abstract

The usage of Wireless Sensor Networks (WSNs) is becoming more common due to the increase in use of wireless devices across communications, IoT, and even wireless charging. The nodes in these networks are small and battery powered that connect through wireless communication and allow information access in areas which human presence is minimal. The life of a network is an essential indexing factor for WSNs mainly dependent on the power consumption of sensor nodes. Studies have been carried out over the years to increase the network life and this is evident in cluster-based routing protocols like LEACH which have shown good results. This paper looks into data aggregation techniques and their pros and cons, and also correlates data aggregation with energy efficiency. Moreover, advanced clustering routing protocols are examined, including the challenges faced while using them.

Keywords

Clustering techniques, Data aggregation, Wireless sensor Networks, Energy Efficiency, Internet of Things

Introduction

Integrated systems with sensing, data processing, and communications capabilities of sensor networks constitute an instance of Wireless sensor networks. These networks are increasingly gaining prominence because of the fact that they collect crucial information from the surrounding. Nevertheless, wireless sensor networks are susceptible to interferences, faults including hardware faults, electromagnetic interference, environmental and network intrusions. Aggregation of data in wireless sensor networks is important in ensuring the energy efficiency and network's lifetime [1]. When aggregating data, there is reduced network traffic and consequently sensor nodes consume less energy. Subsequently, this saves power and enhances bandwidth utility in wireless sensor networks [1] [2]. We present an energy-efficient method of data aggregation in wireless sensor networks. We will strive for this by lowering the number of transmissions and merging sensor data into fewer packets at routing. The method includes combining the sensor nodes with medium- or high-energy load into one packet having summed data of several sensor nodes. Reducing energy consumption related to transmission of single packets will eventually result in extending the entire network life. Furthermore, our approach also takes into account the remaining energy of the sensor nodes in the cluster head

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election process. Besides, we utilize the Gossip algorithm for data aggregation and enhance it to minimize unnecessary transmissions [6]. However, in the wireless sensor networks, it is vital to think on the arising security issues because of data aggregation. Though aggregation of data reduces traffic on networks and reduces energy, it creates new problems of security. Hence, secure data aggregation for wireless sensor network must be adopted [7]. This is done by minimizing the number of transmissions that come about as a result of the merger of the sensor data into a couple of packages during routing. Consequently, the approach aims to increase energy efficiency and prolong network life by reducing transmission frequency.

Understanding Data Aggregation

The act of accumulation of data sourced from various channels into a smaller but convenient format for analysis is known as data aggregation. It is widely used for decreasing huge amounts of data while remaining effective in many application areas like data mining, network communication, databases, and sensor networks among others. Aggregation of data is an essential activity that entails collecting data points or sets, thereby producing a leaner representation that cuts down on storage requirements, communication overheads, and processing complications. There are multiple approaches that are utilized to obtain this, such as averaging, summing, counting, and statistics. Putting things into groups or hierarchy helps to organize information from the first level or basic data. It gives ways to manage data at different levels of details [2] [8]. This organizing system is very important for handling big amounts of information. Data gathering ways are very important for making big amounts of information smaller before sending it wirelessly in network and sensor uses. This helps use less power and reduces traffic on the network. However, reducing data through aggregation is very important for keeping personal information safe and secure. Gathering information together makes it easier to process and send data, takes less space in storage, reduces network use and lets quicker decisions be made with basic facts.

A problem happens when we try to gather and simplify information correctly. We also need to be very careful with different kinds of data and how they fit together, along with stuff like grouping levels. Aggregating information is a crucial way to handle huge amounts of data from different types. This means that smart dust is very important for making networks, managing data, and making decisions. Using it helps to use resources well, handles data better and makes better choices. The methods used to collect data still need a careful balance between reducing data and keeping important information. This is important for things to work well. [3].

The Relationship between Data Aggregation and Energy Efficiency

This is especially critical for data aggregation in wireless sensor networks or distributed computing environments. The principle of conserving energy through minimizing redundant data transmission and efficient network operation lies at the core of this relationship. Data aggregation is also a major consideration in the process of optimization because it reduces data traffic. This is achieved by transmitting aggregated data, either at source or in the intermediate

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nodes of a network thereby reducing the amount of data to be sent. It follows that as far as transmission of a smaller amount of data or reduced data traffic is concerned this leads to fewer transmissions and low energy consumption which is important in a wireless communication system. Sending data aggregate instead of individual raw data points also helps with network congestion. This minimizes traffic and reduces energy consumption through the data retransmissions and collisions in highly crowded networks. Secondly, this translates into less processing overhead at local nodes or edge devices, which in turn facilitates optimization of the processing. This entails gathering data locally and sending the summarized information to reduce the amount of energy-expensive processing at centralized or top nodes and enable local computing. Another benefit is efficient resource utilization where the process of aggregating data reduces the frequent requirement of power consuming components like radios and processors to optimize overall system resource usage. Data aggregation is a valuable energy-saving technique applicable to WSNs, as it prolongs sensor replacement cycles, thereby reducing the need for batteries and charging [4]. Finally, the scalability of WSNs has been increased due to improved data aggregation techniques, which can reduce the additional energy costs and the network's expansion. Nevertheless, there exist trade-offs and challenges like the need for granularity balance in optimization of data aggregation.

In addition, it is important for data volumes to be reduced without affecting the level of granularity needed for meaningful analysis as too much aggregation may lead to loss of details that can affect the quality of insight. There are also issues regarding the security and privacy implications of data aggregation despite the benefits in reducing traffic, optimizing processing, and extending device lifespans. While aggregated data is compact for speed purposes, such information should be handled with care when aggregating since there might still be sensitive information in it. Therefore, effective security strategies should be put in place to protect against possible loopholes and unauthorized intrusion. During the aggregation, the need for encryption, access controls and secure protocols must be taken into consideration to reduce the risk that the sensitive information may be compromised. In order to protect the privacy and security of aggregated data, it is necessary to adopt a proactive position regarding optimization, such that benefits are not derived by sacrificing privacy [5]. The challenge is as technology continues to evolve, organizations need to find ways of balancing the benefits of data aggregation with the highest standards of security and privacy.

It becomes very important to know about data aggregation as it affects energy efficiency within systems, especially in resource less environments like in wireless sensor network. Utilisation of judicious data aggregation techniques reduces power consumed, maximizes resources used and prolongs system duration ultimately boosting energy efficiency in current computing and communication devices [9] [10].

Innovative Approaches to Data Aggregation

With time, data aggregation methodologies will be advancing due to the intricate nature of data sources, instantaneous intelligence requirement and speediness in processing. These innovations, specifically, are geared to increasing the efficiency, reliability, and pace of data integration

processes. Here are some innovative approaches:

Edge computing and edge aggregation denote a new model of computing based on the computational assets found at the network periphery. Here, edge aggregation means compressing data at the source, shrinking the crude data from passing straight to the central computers. This local processing at the edge helps to make rapid decisions, giving real time insights and reducing the latency by accumulating and analyzing the data close to its source. Predictive aggregation using machine learning and predicting future data demand and proactive aggregation to avoid unnecessary transmissions. Threshold-based and context-aware aggregation are adaptive aggregation techniques adjusted according to the network conditions, data type, and contextual data like location and time. Aggregating data together on the blockchain ensures it's done openly and with good quality. It stays unchanged and safe. Mixing ways to aggregate things involves edge computing, machine learning, and other ways. These can make results better by using the good points of each method. Working together, swarm intelligence and group gathering use many things to help them make decisions. This makes the system stronger. These special ways show how information gathering changes all the time. They are made to suit different needs and issues in various areas. Changes in how data is gathered are getting used to the changing needs of handling information [14] [15]. These methods use edge computer improvements, machine learning, flexibility, safety, and teamwork to best collect data. Accepting these new things can make data gathering better, more accurate and bigger. This can happen in different areas and uses.

Approach	Key Features	Advantages	Challenges
Edge Computing and Edge Aggregation	Local processing at edge devices, Realtime insights,	Reduced latency, Quicker decision making	Resource constraints at edge devices, Maintenance of edge infrastructure
Machine Learning and Predictive Aggregation	Predictive aggregation models, Optimized aggregation schedules	Anticipatory data aggregation, Energy efficient data processing	Training and finetuning of models, Complexity of implementing predictive models
Dynamic and Adaptive Aggregation Techniques	Adaptive threshold-based aggregation, Context aware aggregation	Flexibility in adjusting to varying scenarios, Optimized resource utilization	Complexity in determining adaptive thresholds, Context identification and management
Blockchain based Aggregation	Secure and transparent aggregation, Distributed aggregation, and consensus	Enhanced data integrity and transparency, Distributed validation mechanism	Scalability issues in blockchain networks, overhead in maintaining distributed ledger
Hybrid Aggregation Strategies	Integration of multiple techniques for optimal results	Leveraging strengths of different methods, Enhanced efficiency, and accuracy	Complexity in integration, Compatibility issues between different methods
Swarm Intelligence and Collaborative Aggregation	Collective decision making,	Decentralized decision making, Improved system resilience	Coordination among multiple entities, Complexity in designing collaborative systems

Table 1 Comparison of Innovative Approaches to Data Aggregation

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Improving Energy Efficiency in Wireless Sensor Networks

Making wireless sensor networks (WSNs) use less energy is important for making them last longer, growing bigger easily and making sure they work in a way that's good for the environment. Here's a detailed note on strategies and techniques aimed at bolstering energy efficiency in WSNs:

Wireless sensor networks need good power use, and having energy-saving rules is a keyway to do that. Important for this is low-power wireless communication protocols like IEEE 802.11ah, BLE and Zigbee. These on-off ways included in protocols like SMAC or Timeout MACs make sure that nodes turn off to save energy over time. Another important way is to use data combining and squeezing methods to reduce energy use. Using these methods lets us send less information across the whole network. This makes our work faster and more effective. LEACH protocol groups sensor nodes into clusters, saving energy by using layers and middle nodes. We make sure our daily operations are eco-friendly by getting energy from sources like the sun or movement, and also using devices that use less power. Energy efficient adaptive and context-aware systems that use responsive protocols in line with changing circumstances and take into account contextual information optimize utilization of energy. Cross-layer optimization seeks to synergize activities in physically, MAC, network, and application layers while minimizing energy use and maximizing overall network performance. This involves the use of advanced routing techniques like geographic routing and more accurate location estimations that decrease energy on control overhead and localization. Furthermore, sleep/wake strategies as well as traffic management techniques increase efficiency through prioritization of important information and duration of sleep to nodes so that they continue to monitor while conserving energy. Therefore, holistic approach involving variety of ways is critical towards energy efficiency [2] [12] [13].
Wireless sensor network energy efficiency can be increased by combining energy-conscious protocols, data optimization strategies, hardware advancements, and adaptive systems. When constructing sustainable and effective WSNs, striking a balance between energy conservation and network performance remains crucial. More durable, scalable, and energy-efficient wireless sensor networks are being made possible by the combination of many approaches working together as technology develops.

Strategy	Key Features	Advantages	Challenges
Energy aware Protocols	Low power communication, Duty cycling mechanisms	Reduced energy consumption during communication, Efficient power management	Overhead in implementing duty cycling, Balancing energy efficiency with network performance
Data Aggregation and Compression	Aggregation techniques, Compression algorithms	Reduced data transmission and processing overhead, Lower energy consumption during transmission	Balancing data granularity and accuracy, Complexity in compression and decompression algorithms
Clustering and Hierarchical Routing	Clustering schemes (e.g., LEACH), Hierarchical routing	Reduced long distance transmissions, Efficient utilization of hierarchical structures	Overhead in cluster head selection, Network imbalances due to uneven clustering

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Energy Harvesting and Renewables	Energy harvesting technologies (solar, kinetic, thermal), Energy efficient hardware	Sustainable long-term operation, Reduced reliance on batteries	Limited availability of energy sources, Integration challenges with existing systems
Adaptive and Context aware Systems	Adaptive protocols, Context awareness	Dynamic adjustments based on network conditions; Optimized energy usage based on context	Complexity in context identification, overhead in adapting to changing conditions
Cross Layer Optimization	Integration across protocol layers for collective optimization	Collective reduction in energy consumption and improved network performance	Coordination challenges between layers, Complexity in cross layer design
Advanced Routing and Localization Techniques	Geographic routing, Localization algorithms	Minimized control overhead and efficient routing, Accurate node positioning	Accuracy challenges in localization, Scalability issues in geographic routing
Sleep/Wake Strategies and Traffic Management	Traffic management, Adaptive sleep/wake mechanisms	Reduced unnecessary transmissions and optimized traffic, Efficient node sleep/wake schedules	Balancing continuous monitoring with energy conservation, Complexity in traffic prioritization

Table 2: Various strategies for enhancing energy efficiency.

Case Study: Energy Efficient Wireless Sensor Networks

ABC Manufacturing overcame energy efficiency problems with its WSN through integrated measures. ABC was faced with a few limitations in the form of limited battery life, data transmission overheads, and unoptimized protocols. Thus, in order to overcome these obstacles, they deployed solar-powered energy harvesting technology which helped to increase the battery span and reduce node lifespan to This led to a 30% reduction in energy consumption as it eliminated unnecessary data transfers by using data aggregation and compression methods. These mechanisms ensured that the network was reliable and the packet loss was minimal through enhancing data delivery. Enabled adaptation of protocols and context-aware systems that utilized available information about network states, environmental changes, and device states, thereby improving networks' general efficiency. ABC Manufacturing's wireless sensor network was enhanced through the introduction of these energy-efficient solutions. Moreover, the process was very effective and led to a good level of sustainability, reliability and performance for the system. The ongoing evaluation of machine learning-based optimization, as well as enhanced energy capturing devices, will be aimed at improving the network's effectiveness and energy efficiency. The case study demonstrates a successful approach to tackling consumption problems and improving performance in the production of a reliable and durable industrial network operation.

Challenges in Implementing Data Aggregation Techniques

Using methods to combine data can help save on sending it and make better use of network resources. But there are also difficulties that come with this. We need to think hard about how to solve problems that come from collecting data in networks. This is very important. One simple problem is choosing between small details and exactness when joining data. Doing so may

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sacrifice precision for effectiveness. When handling this problem, smart plans and custom limits can reach perfect levels of combining based on the kind of use. When some data is gathered, these worries are still asked because this includes private information [8] [11]. Laws about keeping things private can be followed by protecting data. This can be done using steps like hiding names, making codes, and safe ways to talk. There are differences and matching problems in networks with various sensors and rules. They need middleware or layers to make data formats the same and let them talk. Slow work caused by network problems, making the network heavy and slow to respond. These issues are handled by making algorithms better and using resources well. They look at the right amounts of grouping while doing this. It's hard to keep perfect group methods in changing network situations, but smart tricks can be aware of the situation and adapt to any changes. Smart sleep/wake times and partial grouping methods that save energy can help reduce use of resources. Big designs for making things bigger and automated control systems to keep up with growing networks are the ways to handle these problems. These two goals hope to find a middle ground between the good of data gathering and the difficulties with networks that are spread out and always changing.

It's important to balance data safety, speed, correctness and change within your network limits for a successful use of data collection methods. Beating these problems, data gathering can work well and quickly in many different network situations and uses.

Challenges	Resolution Strategies
Accuracy vs. Granularity Tradeoff	Adaptive aggregation thresholds, Intelligent algorithms for optimized granularity
Security and Privacy Concerns	Encryption techniques, Anonymization methods, Secure communication protocols
Heterogeneity and Compatibility	Middleware for data format standardization, Translation layers for protocol interoperability
Network Overhead and Latency	Optimization of aggregation algorithms, Efficient resource utilization
Dynamic Network Environments	Adaptive and context aware aggregation techniques
Energy Consumption and Resource Constraints	Energy efficient aggregation mechanisms, Intelligent sleep/wake schedules
Scalability and Maintenance	Scalable aggregation architectures, Automated management systems for maintenance

Table 3: Challenges & Resolution Strategies in implementing Data Aggregation

Prospects of Energy Efficiency in Wireless Sensor Networks

The future of energy use in wireless sensor networks can get better and have new ideas. This will help these networks be greener, work well and run smoothly. Here is a look at the chances in this area. Some big changes are coming to Wireless Sensor Networks (WSNs) in areas like energy gathering, improving things, feeling changes, network rules, materials, and toughness. The big worry is finding a way to mix different kinds of energy like sunlight, movement, heat, and radio waves together. This will help give constant power without using batteries. At the same time, we will make energy get smaller and more efficient. We will use parts that are tiny and "greener" in

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each sensor node. This will help it work better. Energy optimization will be crucial in this context and involve predictive analytics. Artificial Intelligence (AI) and machine learning will provide predictions of energy consumption, adjustment of transmissions schedules, and dynamic change of node operations depending on real-time data. Sensor fusion and contextual integration of WSNs will enhance smart sensing and context awareness for optimized energy usage based on sensor inputs like contextual, environmental, and user specific information. It will be possible to conduct real-time contextual analysis at the local level with less data transmission. Further development of energy-efficient communication protocols, as well as the global standards emphasizing the environmental friendliness and the interoperability, will enhance also the eco-friendliness and interoperability of WNS. Energy efficient components such as ultralow power CPU's, communication modules, and sensors will result from advances in nanotechnology. In addition, materials science innovations could see the development of self-powered sensor nodes that would run perpetually drawing energy from their environment. Finally, WSN networks move into resilient and self-healing networks consisting of fault tolerant architectures and dynamic network reconfigurations that optimized energy consumption in case of malfunction, changing demand, and environment influence. Taken together, these developments point to a bright future of WNs; an evolution that will see more energy efficient yet powerful technologies in terms of sustainability. With advances in machine learning, knowing when and where to use power, using renewable energy, and making things in a way that helps the environment, the future of saving energy in devices without wires looks good. These new changes want to build stronger, independent, and nature-friendly networks. They will use the least damage to the environment and serve many different needs.

Conclusion

Data aggregation is very important for energy efficiency in wireless networks with small sensors. Technology greatly lowers the use of energy by changing how we use resources. Putting together data from different places helps manage and send information better. There are some big effects related to how we bring data together and save energy. First, this lowers how much data is sent by bundling and shortening it before sending. This leads to using less power when working with lots of raw data. It also enhances operations, reduces congestion thereby reducing processing needs, thus resulting in less energy consummation by the network. Another significant outcome is having long lifetime of devices which results from using the effective aggregation that ensures reduction in the number of batteries replacement or recharging. Besides, the ability to scale and be resilient increases when data aggregation is used to reduce the number of data involved as this makes the topology of the network smaller and the routing algorithm becomes simpler. Nevertheless, such challenges as maintaining data integrity, security and privacy, and finding the optimal aggregation levels for information grainness are key areas still to be addressed. Overall, data aggregation has a significant positive impact on energy efficiency and provides a means of developing more resilient, efficient, and sustainable systems in a variety of domains. This will help to ensure that data processing and transmission in the future are optimized for low energy consumption without compromising the content of vital information. Undoubtedly, further developments in aggregation techniques and their smooth integration into various systems will open the door to even more ecological and energy-efficient technological

environments.

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EVALUATION OF MECHANICAL PROPERTIES BY PANADANUS TECTORIOUS SHORT FIBRES REINFORCED GAUR GUM MATRIX

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Abstract

Due of their environmental friendliness, natural fibre reinforced composites are very popular nowadays. These are excellent substitutes for petroleum-based goods because synthetic composites are not biodegradable and harm the environment greatly. In addition to being environmentally beneficial, natural fibres are also affordable, lightweight, renewable, and resistant to wear, corrosion, impact, and fire. In this study, a composite was prepared utilising the hand-layup approach employing Pandanus Tectorius (PT) fibre as reinforcement phase and Guargum (GG) as matrix (natural resin). To create environmentally friendly composites, PT Fibres are cut into 4, 8 and 12 mm lengths with various weight contents (5, 10 & 15%) taken into consideration. The goal of this study is to determine the mechanical properties, such as tensile and impact, of pandanus tectorius fibre embedded in a guar gum matrix.

Keywords: Natural Fibre reinforced, Tensile Strength, Impact Strength.

1. Introduction

The people's needs have grown significantly since the dawn of human civilization and the advent of industrial civilization, but at the expense of serious environmental issues brought on by extensive pollution brought on by the careless use of fossil fuels and environmentally hazardous synthetic polymers [1]. A composite is made up of two or more materials combined with reinforcement in the matrix phase. Composites can be made by sandwiching two materials together [2]. Compared to the reinforcing materials, which are robust and less dense, the matrix materials are comparatively ductile and tough. Composites are employed in a range of applications depending on their characteristics [3]. They are made by blending the matrix and reinforcing elements in a range of various ratios. The features of the chemical are synchronised and enhanced by both the matrix phase support and the reinforcing ingredient [4]. Natural resources including wood, clay, stones, dirt, metals, tree gums, etc. have been used since the Stone Age and by early civilizations, and early humans increasingly perfected their utilization [5]. But as the Industrial Revolution began and science and technology evolved, people created synthetic materials that seriously affected the environment [6]. Due to the steady depletion of natural resources and the growing population, natural fibres and composite materials have the potential to replace synthetic ones [7]. The bulk of natural fibres are obtained from trees without

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harming them since they are biodegradable organic compounds that are often sourced from animal waste and plants [8]. Natural composites can eventually replace synthetic composites and minimise environmental pollution to a greater extent with equivalent properties, even though their properties may not be as good as those of synthetic materials at this moment [9]. Synthetic fibres with comparable qualities can also be replaced by natural fibres [10]. The classification of a natural fibre is frequently based on where it was produced [11]. These parts are referred to as natural fibre reinforced bio composites because they blend natural fibres with environmentally favourable, pollution-free, and biodegradable ingredients [12]. In order to meet human requirements and lessen the greenhouse effect, natural fibre composites are crucial. We obtain our natural fibres from trees, a nearly limitless resource that is a source of renewable energy. How dependable and high-quality the compound or composite is depends on the type of resin [13], gum, quantity, length, form, and matrix arrangement. Natural fibres are mostly made of lignin, carbohydrates, cellulose, and other water-soluble materials [14].

2. Materials and Methods

2.1. Materials and Composite Preparation

The use of guar gum powder and Pandanus Tectorious fibres (PT fibres) was employed in the fabrication of a green composite material, with the aim of investigating its mechanical characteristics. The particles of guar gum powder were consistently maintained at a size of around 200 mesh. The chemical and physical parameters of the guar gum powder are shown in **Table 1**. The solubility of guar gum in both hot and cold water makes it a suitable foundation for our environmentally sustainable matrix. The raw powder of guar gum was provided by Marine hydrocolloids, a firm based in Kerala, India.

In a similar manner, untreated PT fibres were used in the fabrication of green composite materials. The fibres were divided into three distinct sizes, namely 4 mm, 8 mm, and 12 mm in length. Furthermore, the utilisation of these chopped short fibres was seen in green composites with varying fibre loadings, namely at 5%, 10%, and 15%. By using optimisation techniques with a single time variable, we were able to identify the process parameter that governs the mechanical properties. The short fibre, manufactured beforehand, was dehydrated at ambient temperature and stored in a desiccator to avoid exposure to the surrounding environment. **Table 1** presents the essential attributes of resin and fibres.

In the first stages of preparing guar gum bio-resin, a preliminary experiment was conducted. The objective was to retain the optimal characteristics of guar gum resin. To do this, a quantity of 150 g was accurately measured and gradually introduced into 400 ml of distilled water. The mixture was continually stirred using a mechanical mixer for duration of 30 minutes, ensuring the attainment of a uniform blend. In addition, many additional compounds are used to regulate the pH of the matrix material and enhance cross-linking by including glutaraldehyde. In order to achieve neutralization of the blending matrix, a solution containing 8g of NaOH diluted in 180 ml of distilled water was introduced. To promote the interconnection of the matrix material, a volume of 42 ml of Glutaraldehyde was introduced, followed by vigorous agitation to ensure uniform dispersion. Multiple permutations of green composite mats were created by repeating the method, whereby varied fibre lengths and fibre content were combined. These mats were

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then used for a variety of cauterizations.

A mould with dimensions of 250 mm x 250 mm x 3 mm was constructed to accommodate semi-solid green composite material during the manufacturing process of green composite laminates. A mold-releasing substance, namely wax, was used to coat the cavity of the mould. This application aids in the extraction of the cured green composites. The aforementioned technique was repeated for the remaining composites. The green composite material, which had been produced in advance, was carefully inserted into the cavity of the mould. It was then compacted to ensure that it reached all corners of the mould, and afterwards leveled to achieve the appropriate thickness and smoothness of the laminate surface. During the course of this treatment, it was noticed that the short fibres oriented randomly and distributed inside the matrix material. The laminates, in their as-prepared state, were subjected to a compressive force of 100 kg and then cured at ambient temperature for duration of 72 h.

Table 1: Pandanus Tectorious fiber and gaur gum powder typical chemical properties.

Parameters	Pandanus Tectorious fiber	Gaur gum resin
Appearance	---	Off white color
Moisture (%)		7
Ash	---	1.53%
Protein	---	4.00%
pH	---	6.5
Viscosity	---	7200 cps
Solubility	---	In cold and hot water
Particle size 200 mesh	4 mm, 8 mm, & 12 mm	99.6%
Nature	Hydrophilic	Hydrophilic
Cellulose (wt %)		---
Hemi cellulose (wt %)		---
Lignin (wt %)		---

Table 2: Composite coding for green composite material

Composite Code	Composite composition		
	Fiber length (mm)	Fiber Content (wt %)	Gaur Gum Resin (wt %)
GGR	--	--	100
UPTG0405	04	05	95
UPTG 0410	04	10	90
UPTG 0415	04	15	85
UPTG 0805	08	05	95
UPTG 0810	08	10	90
UPTG 0815	08	15	85
UPTG 1205	12	05	95
UPTG 1210	12	10	90
UPTG 1215	12	15	85

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2.2. Mechanical Characterization

2.2.1. Tensile Characterization

The tensile strength of newly developed green composites was measured using an universal tensile testing equipment (AE-30 kN, Advanced Equipment, India) following the guidelines set by ASTM-D638 standards, as seen in **Fig. 1 (a)**. The tensile tests were conducted using atmospheric circumstances and a crosshead displacement rate of 5 mm/min. The specimens used in this study were dog bone-shaped and had dimensions of 165mm in length, 19mm breadth, and 3mm thickness. The gauge width of these specimens measured 13 mm, while the gauge length was recorded as 57mm. Every group consisted of three test specimens. The results were calculated using average values. The test samples were positioned in a vertical orientation inside the clamps of the machine. The gauge length was consistently kept at a measurement of 57mm, and the grips were set in a uniform and secure manner to prevent any instances of slippage or excessive friction when gripping. Governing Eq. (1) was employed to calculate the tensile strength (σ_t):

$$\sigma_t = \frac{F}{b \times t} \quad (1)$$

Where (σ_t) is the tensile strength of the sample, (F) is the maximum tensile load at which the sample fails physically, and (b & t) are the sample breadth and thickness, respectively.

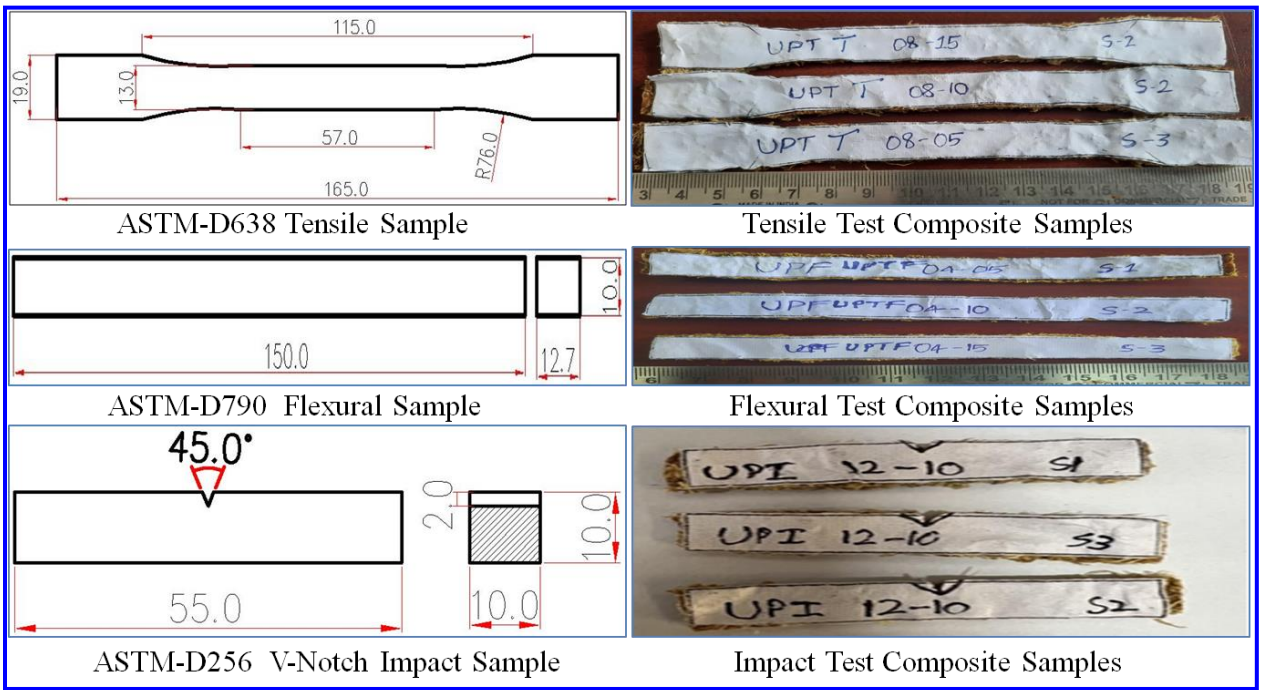


Fig. 1: (a) ASTM-D638 tensile test sample dimensions and green composite samples, (b) ASTM-D790 sample dimensions and green composite samples, (c) ASTM-D256 sample dimensions and single V-notched Izod impact green composite samples. All dimensions in mm.

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2.2.2. Flexural Characterization

Frequently, flexural testing is conducted in order to evaluate the flexural properties of green composites. The present work aimed to assess the flexural strength of a green composite material. This evaluation was conducted using an universal flexural testing equipment (AE-30KN, Advanced Equipment, India) in line with the ASTM-D790 criteria. Refer to **Fig. 1 (b)** for a visual representation of the experimental setup. The flexural specimen has dimensions of 150 x 10 x 3 mm. Every experimental trial has three distinct samples, and the mean outcomes for each trial were reported. The experiment was performed by subjecting the specimen to a force using a three-point bending configuration. The rate of crosshead displacement on the samples was consistently maintained at 5 mm/min until the point of specimen failure. The flexural strength was calculated by using the force-displacement data and equation (2). The evaluation of the flexural properties of green composites is of utmost importance in determining the material's effectiveness in various technological applications.

$$\sigma_b = \frac{3Fl}{2bt^2} — (2)$$

Where (σ_b) is the flexural strength of the sample, (F) is the maximum bending load at which the sample physical failure, and (b & t) are the specimen's breadth and thickness, and (l) is length of specimen, respectively.

2.2.3 Impact Characterization

The measurement of impact strength is used to assess the capacity of a material to absorb energy and withstand fracture under the influence of an abrupt force or shock. The feature in question has significant importance in the context of green composites, since it governs the material's capacity to endure impacts and shocks without experiencing fracture or cracking. In this study, a computerized Izod/Charpy impact testing equipment (model AE-ICIT-FC) provided by Advanced Equipments, India, was used. The machine was utilised in accordance with ASTM-D256 regulations, as seen in **Fig. 1 (c)**. The equipment used a resolution of 0.0001J and maintained a consistent pendulum speed of 3.46 m/s in order to complete the impact test on all samples. The experimental procedure included the preparation of single V-notched impact samples, which were then placed into the machine in accordance with the established standards. The equation (3) used for the determination of the impact strength of a material is as follows:

$$\text{Impact Strength (J)} = \frac{\text{Impact Energy}}{\text{Cross} - \text{sectional Area}} — (3)$$

3. Results and Discussion

The green composite material has been tested for its mechanical properties, revealing superior tensile and flexural strength compared to other green composite materials. However, it has reduced impact strength, indicating higher brittleness and fracture susceptibility. The material's enhanced tensile and flexural performance is evident, but its impact resistance is diminished. The study explores potential factors contributing to these findings in subsequent sections. The results suggest that green composites may have potential applications in various industries.

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3.1 Tensile strength

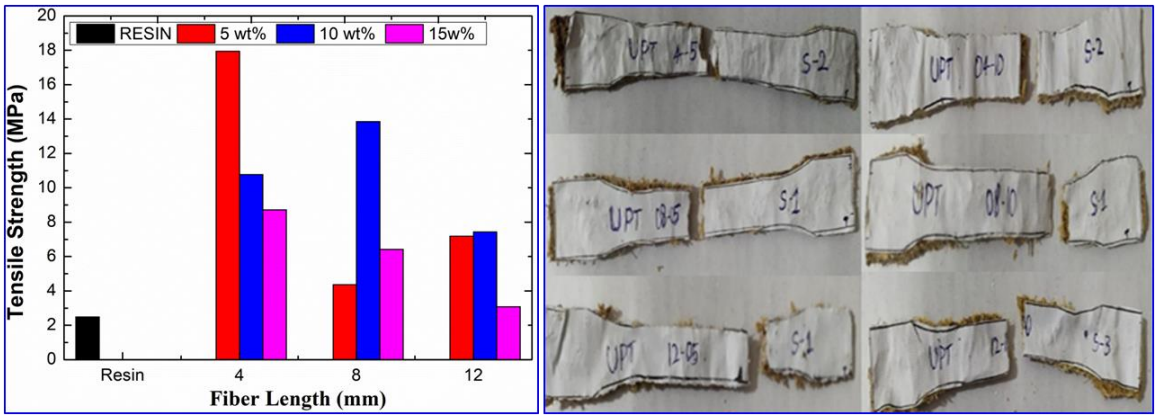


Fig. 2**: Tensile strength of randomly oriented UPT fiber and Gaur gum composite material as a function of fiber length and fiber loading percentage, as well as fractured samples, as measured during tensile characterisation.**

The investigation focused on analyzing the tensile strength of a composite material made from Pandanus Tectorious fiber and guar gum resin. The results, shown in Fig. 2, demonstrated varying outcomes for various compositions. It observed that the neat resin exhibited tensile strength of 2.49 MPa. To improve the tensile properties, short fibers were incorporated in the matrix material with different fiber lengths and fiber loadings and mechanical performance reported. Due to the reinforcement in the matrix material, overall tensile strength of composite material enhanced. The tensile strength of UPTG0405 composite material achieved 17.95 MPa, which is 620% higher than the neat resin and other composite materials. It seems that the 4 mm short fibers and 5 wt% of fiber loading are effectively reinforced the resin material and transfer the load from the resin to the fibers. Similarly, UPTG0805 and UPTG1205 composite materials tensile strength was reduced to 75.7% and 60%, respectively, in compare with UPTG0405 composite material. This is due to increase in the fiber length, which leads to more fiber-fiber contact area rather than matrix-fiber contact area and this reduces the interfacial bond.

In a comparable research on tensile properties, the green composite materials UPTG0410, UPTG0810, and UPTG1210 exhibited 10.77 MPa, 13.85 MPa, and 7. 44 MPa, respectively. It has been shown that fiber length plays a crucial role in bearing tensile loads, while maintaining a constant fiber loading of 10 wt%. When the fiber length increases from 4 mm to 8 mm, the tensile strength increases 28.59% and further increase in length to 12 mm, the tensile strength of composite reduces to 86.15%. The fact behind is because of agglomeration of the fibers and further reduces the interfacial bonding between the fiber and matrix. It found the optimal fiber length is 8 mm with the combination of fiber loading 10 wt%.

In contrast, the green composites UPTG0415, UPTG0815, and UPTG1215 exhibited tensile strengths of 8.72 MPa, 6.41 MPa, and 3.08 MPa, respectively. A notable and consistent reduction in the tensile strength of the green composite materials was seen as the length of the fibers increased from 4 mm to 12 mm. Such phenomenon due to cohesive forces developed strongly between the fibers and leads to agglomeration. The result indicated above emphasizes

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the significant impact of fiber length on the mechanical properties of the composite material, suggesting that longer fibers contribute to the negative effect on tensile strength, which is a critical aspect in the domain of material engineering and design.

This discovery highlights the importance of fiber loading in composite materials, since increasing percentages of fiber loading have been shown effectively reduce the tensile characteristics of these environmentally friendly composites. Since a result, these findings have tremendous potential for a wide range of applications. The UPTG0405 composite was identified as having the maximum tensile strength among the composites examined. The findings indicate that the UPTG0405 composition exhibited superior overall strength in comparison to the other composites. The aforementioned findings underscore the influence of varying composite compositions on tensile strength, hence highlighting the potential for tailoring material properties to meet specific application requirements.

3.2. Flexural Strength

The outcomes indicate that the flexural strength of the composites is influenced by both the length of the fibers and the amount of fibers present. The flexural strength of a material is determined by many factors, including the quality of the interfacial bonding between the fibers and the resin, the orientation of the fibers, and the distribution of the fibers inside the material. The following are some probable causes of composite failure:

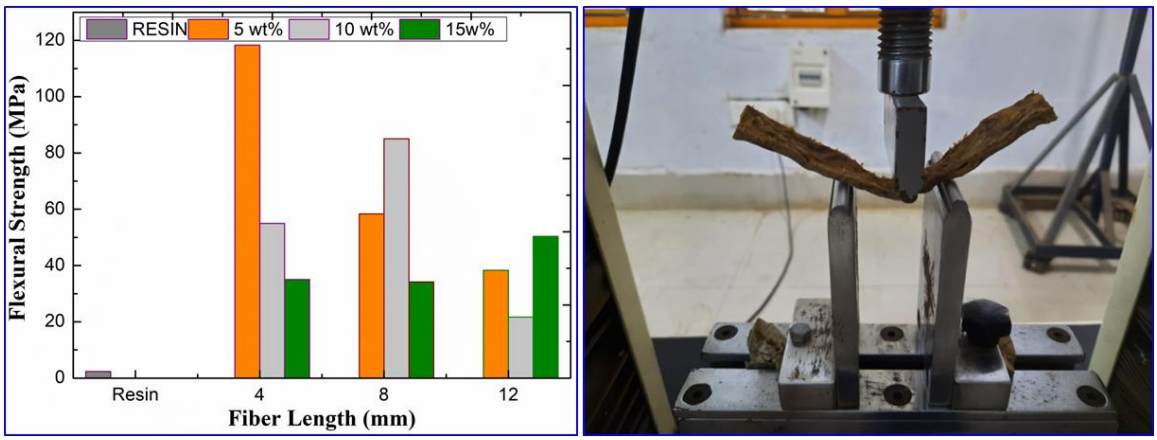


Fig. 3: Flexural strength analysis of randomly oriented UPT fiber and Guar gum composite material: investigating the **effects of fiber length, and fiber loading percentage, and flexural loading on sample.**

To improve the flexural strength of natural composite material, the flexural strength of the gaur gum resin matrix was shown 2.35 MPa and reinforced with short random oriented fiber. Fiber lengths of 4 mm, 8 mm, and 12 mm with fiber loadings of 5 wt%, 10 wt%, and 15 wt%. The flexural strength of the UPTG0405 composite material was the greatest of all the composites is 118.33 MPa. Because of its modest fiber loading of 5% and short fiber length of 4 mm, it provides strong interfacial bonding and homogeneous fiber dispersion. The fibers are also randomly oriented, which gives the resin isotropic reinforcement. Similarly, flexural strength of UPTG0410 and UPTG0415 is lower than that of UPTG0405 composite. This is due to their greater fiber loadings of 10% and 15%, respectively, which results in poor interfacial bonding and fiber aggregation. Additionally, the fibers are more likely to be oriented parallel to the

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loading direction, reducing the reinforcing effect.

The UPTG0805 composite has a comparatively lower flexural strength when compared to the UPTG0405 composite. This phenomenon may be attributed to the longer fiber length of 8 mm, which therefore leads to a reduction in the area of contact between the fiber and matrix, while simultaneously increasing the area of contact between fibers. The extended fibers are also susceptible to deformation and instability when subjected to a load, hence diminishing the efficiency of load transmission. Further, flexural strength of the UPTG0810 composite was found to be greater compared to that of the UPTG0805 composite. This phenomenon may be attributed to the presence of a greater fiber loading of 10 wt%, which serves to counterbalance the adverse impact stemming from the increased length of the fibers. Increasing the fiber loading also enhances the stiffness and rigidity of the composite material. The composite material UPTG0815 exhibited a decreased flexural strength compared to the UPTG0810 composite. This phenomenon may be linked to the substantial fiber loading of 15wt%, beyond the optimum limit for this specific fiber length. The use of a significantly elevated fiber loading leads to the occurrence of pronounced interfacial debonding and fiber pull-out phenomena, hence resulting in a notable reduction in the overall strength and integrity of the composite structure.

The flexural strength of UPTG1205 composite is comparatively lower than that of UPTG0805 composite. This is attributed to the elongated fiber length of 12 mm, which therefore leads to inadequate interfacial bonding and fiber dispersion. The elongated fibers have a high susceptibility to deformation via bending and buckling when subjected to a load, hence compromising the efficiency of the load transmission mechanism. Additionally, flexural strength of UPTG1210 composite is comparatively lower than that of UPTG1205 composite. This may be attributed to the elevated fiber loading of 10 wt%, which exacerbates the adverse impact of excessively long fiber length. The increased fiber loading also leads to elevated stress concentration and fracture initiation at the ends of the fibers, thereby diminishing the fracture toughness of the composite material. In a similar vein, it can be seen that the UPTG1215 composite exhibits a greater degree of flexural strength when compared to the UPTG1210 composite. This phenomenon may be attributed to the substantial fiber loading of 15 wt%, which effectively reinforces the resin, even in the presence of quite long fiber lengths. The significant increase in fiber loading also results in an increase in the cross-sectional area and moment of inertia of the composite material, hence enhancing its resistance to bending.

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3.2 Impact strength

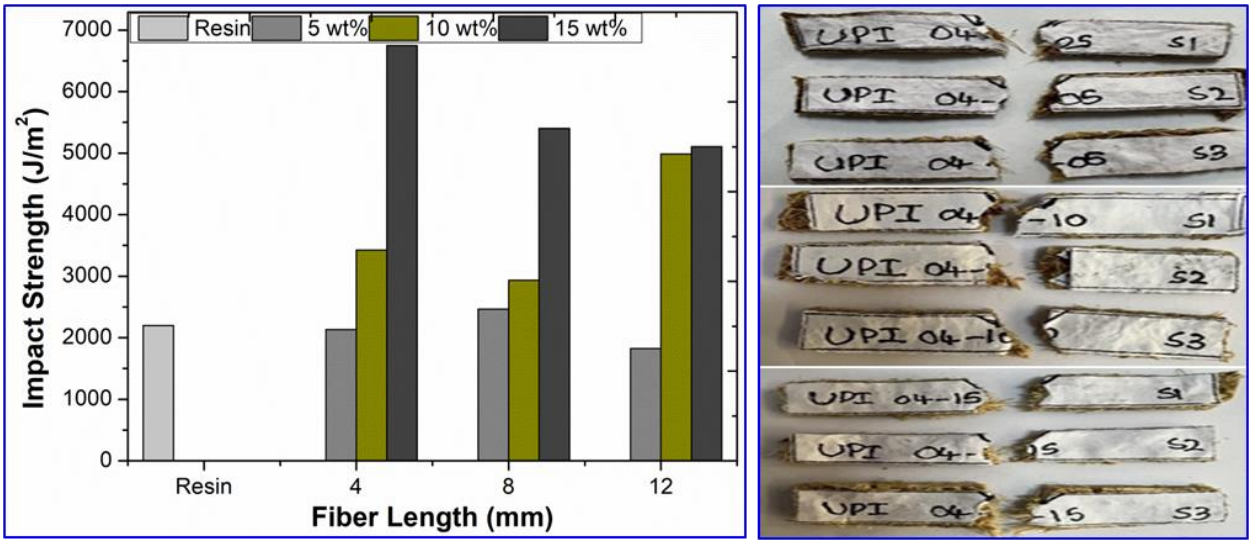


Fig. 4: Impact strength of randomly oriented UPT fiber and Gaur gum composite material with varying the fiber length and fiber loading percentage and fractured samples during the impact characterization.

The impact strength of the PT/GG resin green composite material is shown in the F**ig.4**. The impact strength of the neat guar gum resin material was 2198.33 J/m^2 achieved. Short randomly oriented PT fibres were introduced at varied fibre lengths and fibre loading weight percentages to improve the resin's strength qualities, yielding diverse outcomes. Overall, the green composite material's impact strength improved somewhat. Notably, the composite with a 15 wt% fibre loading was displayed outstanding impact resistance. The impact strengths of the UPTG0415, UPTG0815, and UPTG1215 green composites were 6749.78 J/m^2, 5403.32 J/m^2, and 5104.98 J/m^2, respectively. Among them, the PTG0415 composite demonstrated a significant increase in impact resistance, demonstrating its promise for applications where impact strength is critical consideration.

4. Conclusion

Therefore, the present study effectively produced natural composite materials using short pandanus tectorius fibre and Gaur gum resin by the hand layup technique. Subsequently, the mechanical performance of these materials was evaluated in terms of tensile, flexural, and impact-strength. Overall, the reinforced composite material mechanical properties was enhanced in compare with neat Gaur gum matrix. The current study yielded the following findings:

- The tensile strength of UPTG0405 composite material achieved 17.95 MPa, which is 620% higher than the neat resin and other composite materials. It seems that the 4 mm short fibers

and 5 wt% of fiber loading are effectively reinforced the resin material and transfer the load from the resin to the fibers.

- The flexural strength of the UPTG0405 composite material was the greatest of all the composites is 118.33 MPa. Because of its modest fiber loading of 5% and short fiber length of 4 mm, it provides strong interfacial bonding and homogeneous fiber dispersion. The fibers are also randomly oriented, which gives the resin isotropic reinforcement.
- The impact strength of UPTG0415 composite material recorded highest of all the composites is 6749.78 J/m^2.

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CFD ANALYSIS OF WIND TUNNEL WITH SHAPE VARISTIONS IN LOOP

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Abstract

Wind tunnels play a crucial role in aerodynamic research and development, serving as indispensable tools for testing and validating various designs. However, losses in the flow, such as turbulence and pressure drops, can compromise the accuracy and reliability of experimental results. This paper presents a comprehensive investigation into the reduction of losses within the flow of a wind tunnel through the application of Computational Fluid Dynamics (CFD) analysis using ANSYS software. This work investigates the effects of corner angles—particularly the change from 90 to 45 degrees—on aerodynamic performance in closed-loop wind tunnels. The study looks into head losses and provides a thorough analysis of how they affect aerodynamic performance. The study attempts to close a gap in the literature by quantifying these losses using computational methods and focuses on corner angles and particular losses suffered. The results have potential applications in wind energy, aircraft, and flow management, and they have practical implications for creating more efficient engineered structures. For real-time optimization, artificial intelligence integration is also taken into consideration. The approach, theoretical foundation, experimental findings, and ramifications for upcoming engineering projects will all be covered in detail in the following parts.

Keywords

Wind tunnel, Calculation of head losses, CFD analysis, Simulation of flow pattern, Corner angles.

Introduction

A wind tunnel is a specialized facility designed for testing the aerodynamic characteristics of objects, such as aircraft, vehicles, or structures, in a controlled and repeatable environment. It consists of a closed passageway through which air is forced to flow at controlled speeds, simulating the conditions an object might experience in real-world applications. The primary goal of a wind tunnel is to study the effects of airflow on a model or prototype, helping engineers

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and scientists analyze lift, drag, stability, and other aerodynamic factors. Wind tunnels play a crucial role in the development and testing of aerospace technologies, as well as in various other fields such as automotive engineering, sports equipment design, and architectural studies.

The research employs Computational Fluid Dynamics (CFD) to comprehensively investigate the design, simulation, and analysis of flow parameters, aiming to assess the precision of replicating intended flow characteristics through numerical simulations [1]. Their is importance of wind tunnels in studying aerodynamics for low-speed vehicles like UAVs and MAVs. An 1.8m open-circuit wind tunnel with an 8m/s flow velocity in a square test section is created, using ANSYS Workbench for numerical flow simulation. The construction involves Mild Steel components, and calibration includes measuring test section velocity at different fan speeds with a pitot-static probe. A reliable experimental setup for investigating aerodynamics, especially in the context of low-speed flight conditions for UAVs and MAVs is established [2]. Design and simulation of flow parameters in a closed-loop wind tunnel using Computational Fluid Dynamics (CFD) is investigated. Unlike conventional methods, it employs a full-scale model of the entire wind tunnel, focusing on optimizing flow quality throughout the circuit. The study emphasizes the impact of upstream flow conditions on test section flow quality, particularly in guide vane configurations. Validation with a block model demonstrates that CFD can replicate wind tunnel measurements with an error below 10%, highlighting the importance of a holistic approach to wind tunnel design and the successful application of CFD for accurate simulation and validation [3]. Velocity of 25 m/s is achieved in test section. Key features include a 500 mm square test section, a stabilizing straight section, and a straight contraction profile transitioning to an octagonal diffuser. Calculations for pressure drop, power requirements, and a tunnel performance curve are presented, emphasizing the importance of computational validation before construction [4].

Globalization has interconnected the world, leading to widespread environmental challenges. One major issue is air pollution, which can be controlled through wind tunnel simulation. India aims to meet its defense and air transport needs through domestic aircraft design and manufacture, necessitating large wind tunnels for testing [5]. In the context of aerodynamic research, the efficient design and simulation of a redesigned closed-loop wind tunnel pose significant challenges. This study aims to systematically investigate the flow parameters of a modified closed-loop wind tunnel, transitioning from a standard rectangular shape to a triangular configuration using SolidWorks and Computational Fluid Dynamics (CFD). The simulation results, obtained using the ANSYS commercial program, indicate that the velocity within the test section remains constant. This validates the effectiveness of the design and provides confidence in the performance of the wind tunnel [6]. The primary motivation for this modification is to reduce head losses by minimizing the number of corners in the wind tunnel. The closed-loop wind tunnel operates under subsonic conditions, necessitating careful consideration of inlet conditions. The inlet velocities are determined by applying the Continuity equation at the effuser and test section. However, the use of a closed-loop wind tunnel introduces challenges, including the generation of heat due to repeated air circulation and head losses caused by radiators. To address these challenges, a Guide Vane Radiator system is designed to direct air circulation effectively, cool the circulating air, and reduce overall head losses. The heat transfer within the guide vane radiators is studied, and relevant equations are applied to determine the conditions of the inlet water flow. The proposed solution involves the redesign of the closed-loop wind tunnel

into a triangular shape, incorporating the Guide Vane Radiator system. The objective is to enhance the overall efficiency of the wind tunnel by mitigating heat-related issues and minimizing head losses. The effectiveness of the design is evaluated through simulation to ensure optimal aerodynamic performance and adherence to subsonic conditions. The initial analysis are crucial for the design of a wind tunnel, providing valuable insights for constructing a facility that generates reliable results in line with numerical data. Ongoing efforts at different institutes focus on integrating Computational Fluid Dynamics (CFD) techniques into wind tunnel design. Numerical analyses can be done to support the design of model suspension systems and flow straighteners, aiming to optimize experimental accuracy and efficiency [7].

The methodology outlined in this text describes the modification of a regular rectangular-shaped closed loop wind tunnel to a two-corner (45° each) triangular type in order to reduce major head losses. Here's a breakdown of the steps and considerations in this methodology

- Identification of Head Losses: Identify that the major head losses in the wind tunnel are occurring at the four corners and due to the radiator. Understanding the sources of head losses is crucial for designing an effective modification.
- Modification Design: Propose a design modification by changing the shape of the wind tunnel from a rectangular one to a triangular one with only two corners at 45° each. This design change aims to reduce the overall head losses in the system.
- Head Losses at 45° Corners: Acknowledge that the 45° corners in the triangular wind tunnel design contribute more to head losses compared to a 90° corner. This recognition is important for evaluating the trade-offs involved in the design change.
- Compensation for Head Losses: Argue that despite the higher head losses at 45° corners, the overall head losses can be compensated due to the reduced number of corners in a triangular-shaped wind tunnel (2 corners) compared to a rectangular one (4 corners).
- Role of Guide Vanes: Highlight the importance of guide vanes in ensuring uniform fluid flow, especially at corners. The guide vanes play a crucial role in minimizing non-uniform flow, as non-uniform flow can negatively impact the accuracy and reliability of experimental results conducted in the test chamber.
- Consideration of Radiator: Ensure that the modification takes into account the cooling requirements for the radiator. The change in geometry should not compromise the efficiency of the radiator in cooling down the heat generated by the continuously flowing fluid.

Literature Review:

Various wind tunnels of close loop type have been existed and being developed for applications in aerodynamics and wind engineering. Now-a-days these are being applied for experimentation of PCB cooling.

The article provides foundational data for a subsequent study titled 'A validated design methodology for a closed-loop subsonic wind tunnel' (Calautit et al., 2014). The research focuses on a systematic investigation into the design, simulation, and analysis of flow parameters within a wind tunnel using Computational Fluid Dynamics (CFD). The authors aim to assess the

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precision of replicating the intended flow characteristics of the wind tunnel through numerical simulation. The current article outlines the experimental and numerical setups employed for the analysis of the closed-loop subsonic wind tunnel, specifically when the test section is empty.
The article highlights the crucial role of wind tunnels in aerodynamic studies, focusing on their importance in understanding the behavior of bodies, especially for vehicles like UAVs and MAVs operating at low speeds. It describes the design and fabrication of a small-scale open-circuit wind tunnel with a 1.8m length, aiming for an 8m/s flow velocity in a square test section. Numerical flow simulation using ANSYS Workbench is used to analyze flow characteristics. Components are made of Mild Steel, and calibration involves measuring test section velocity with a pitot-static probe at various fan speeds. The overall objective is to establish a reliable experimental setup for studying aerodynamics, particularly in the context of low-speed flight conditions for UAVs and MAVs. These paper outlines the process of designing an open circuit subsonic wind tunnel intended for studying the wind effects on various prototypes of structural elements. The design procedure follows established guidelines and prior research findings, with three design trials conducted to achieve a test section velocity of 25 m/s. The final design features a square test section of 500 mm side length, a straight section preceding the test chamber for stabilization, and a straight contraction profile with a larger length instead of a curved wall shape. The diffuser transitions from a square test section to an octagon of 311 mm side. The paper includes calculations for pressure drop, power requirements, and presents a tunnel performance curve. It emphasizes the need for computational validation before actual construction. Despite its empirical nature, the design attempts to contribute to research applications in the existing setup.

Modeling

DESIGN OF 90° CORNER:

- Develop the outline of the vane in such a way that the inlet and outlet are of lengths 0.75m, their perpendiculars coincided at 90° to each other and the inlet and outlet are joined by arcs of radii 0.075m and 0.150m as shown.
- Draw the 90° corner with inlet and outlet.
- For the guide vane, the available length of inlet and outlet (0.75m) is divided into 9 equal parts each of length 0.075m.

DESIGN OF 45° CORNER:

- Develop the outline of the vane in such a way that the inlet and outlet are of lengths 0.75m, their perpendiculars coincided at 45° to each other and the inlet and outlet are joined by arcs of radii 0.075m and 0.150m as shown.
- For the guide vane radiators, the available length of inlet and outlet (0.75m) is divided into 10 equal parts each of length 0.075m.
- Develop a provision for guide vane radiator taking 0.15m as lower circle radius and center as that point which is used for developing an arc of 0.075m radius (used for joining the inlet and outlet) .The radius of the upper arc of the guide vane radiator

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should be taken as 0.075m and a suitable center such that all the nine vanes are equally spaced. The two obtained arcs are then joined by lines. A chamfer of radius 0.005 is given at the corners to obtain the guide vane radiator.

- Similarly provisions for all the nine guide vanes are developed.

As we can see fig1.(a) and fig2.(a) shows 45° corner and fig1.(b) and fig2.(b) shows 90° corner. They are developed such that the inlet and outlet of both the corners comprises the same length and the area of the flow is also the same.



(a) (b)

Fig.1. (a) geometry of 45° corner; (b) geometry of 90° corner.



(a) (b)

Fig.2. (a) geometry of 45° corner with guide vane;

(b) geometry of 90° corner with guide vane.

Meshing

Mesh parameters: proximity min size, max face size, max size, coarse relevance, medium smoothing, and sizing based on curvature and proximity are all determined by carefully balancing the need to accurately capture geometric details with the constraints of computing power. The mesh is guaranteed to accurately reflect the geometry via proximity and curvature-based sizing, while coarse relevance strikes a compromise between accuracy and processing power. In order to manage mesh density and computational cost, the selected sizing parameters, such as proximity min and max sizes, are customized to the geometry and simulation needs. To improve mesh quality while controlling computational costs, medium smoothing is used. Overall, in order to create a mesh that best combines accuracy and computing economy, these parameters are refined through repeated testing and experience.

STEPS:

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- Right click to the Mesh → Edit, to the body
- Sizing: on the proximity and curvature for better results, due to computational limits of Relevance: coarse, Smoothing: medium
- Proximity min size:0.4 cm, Max face size:46 cm, Max size:92 cm
- Mesh is generated, Mesh → Generate mesh, Inlet and outlet conditions are defined using named selections

Setup

The final values in ANSYS's setup section are probably determined by the particular needs and features of the simulation being run. The use of four processors for parallel processing and double precision is intended to decrease computing time and improve numerical accuracy, respectively. The kind of flow being simulated and the reference frame for velocity measurements are indicated by setting the general type to pressure-based with absolute velocity formulation. The choice of 9.81 m/s2 for both stable time and gravity implies a steady-state simulation that takes gravitational influences into account. The kind of flow and required degree of turbulence modeling accuracy determine which turbulence model is used, such as k-epsilon with realizable and improved wall treatment. The Fluent database is used to provide material attributes while taking the simulated fluid—in this example, air—into account. The geometry and physics of the issue are used to define cell zone conditions and boundary conditions, which include material specifications and inlet and outlet conditions, with the goal of properly representing real-world circumstances and boundary interactions inside the simulation domain. To get accurate and effective simulation results, these parameters are ultimately determined by combining optimal simulation methods, a knowledge of the problem's physics, and repeated testing.

STEPS:

- Setup → Edit → Double precession on → Parallel 4 processers is set → OK
- General Type → Pressure based, Velocity formation → Absolute, Time → Steady Gravity = 9.81m/s
- Modes k-epsilon → Realizable →Enhance wall treatment
- Materials Fluent database → air → copy
- Cell zone condition Add material → air → OK
- Boundary conditions Air inlet → velocity inlet = 0.5 m/s Air outlet →pressure outlet = 0 pa

Air flow with and without guide vanes

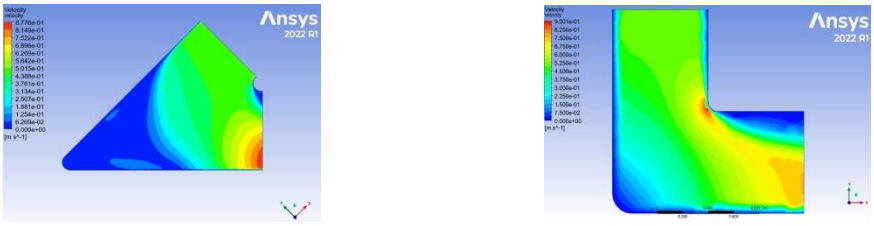
Taking the same boundary conditions for both the corners, flow simulation has been done to get the flow properties using ANSYS FLUENT with and without guide vanes.

The velocity contours obtained are as follows:

Figure3. (a and b) shows air flow in 90° and 45° corners without guide vane.

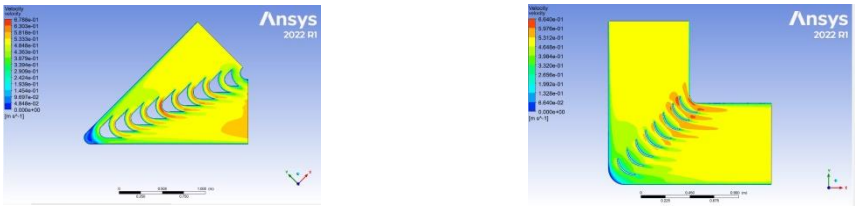
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Figure4. (a and b) shows air flow in 90° and 45° corners with guide vane.



(a) (b)

Fig.3. (a) 45° corner without guide vane; (b) 90° corner without guide vane.

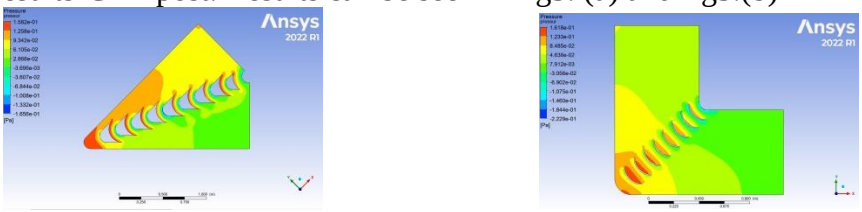


(a) (b)

Fig.4. (a) 45° corner with guide vane; (b) 90° corner with guide vane.

Results-CFD post HEAD LOSS AT THE CORNERS:

In order to calculate head losses, average pressures at the inlet and outlet of 2D corners are found using a functional calculator, and pressure simulations for both corners with guide vanes are completed in Results-CFD post. Results can be seen in fig5. (a) and fig5.(b)



(a) (b)

Fig.5. (a) Presser in 45° corner; (b) Presser in 90° corner.

Table.1. (a) shows the difference between 90° and 45° corner.

Table.1. (a) Difference b/w 90° and 45° corner

90° corner	45° corner
Average of pressure at inlet P1 =0.041552 Pa	Average of pressure at inlet P1 =0.0760763 Pa
Average of pressure at outlet P2 = 0 Pa	Average of pressure at outlet P2 = -1.18599e-05 Pa
Head loss = $\Delta p/ \rho g$	Head loss = $\Delta p/ \rho g$
p = density of air 1.225 kg/m³	p = density of air 1.225 kg/m³
g = gravitational acceleration 9.81 m/s²	g = gravitational acceleration 9.81 m/s²
Head loss = 0.003457m	Head loss = 0.006331m

Since there are 4 corners in rectangular wind tunnel the overall head loss due to corners is 4 times the head loss of a 90° bend and it will also have radiator head loss if it is introduced.
90° Overall head loss = 4*head loss due to 90° corner + radiator head loss

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= 4*0.003457 + radiator head loss
= 0.013828 m + radiator head loss

But in the conceptual triangular shaped wind tunnel will have 3 corners in which two of them were 45° corners the other corner is compensated by a centrifugal blower for circulation of air where there is an advantage of involving radiator within the guide vane itself. So overall head loss due to corners is 2 times the head loss of a 45° bend.

45° Overall head loss = 2*head loss due to 45° corner
= 2*0.0063315
= 0.012662 m

Here as the overall head loss in 45° corner is less than the overall head loss in 90° corner, the 45° is preferred to reduce the overall head loss.

Conclusion

To sum up, this thorough investigation of the impacts of altering corner angles in closed-loop wind tunnels—specifically, the shift from 90 to 45 degrees—offers insightful knowledge about the complex field of aerodynamics. By measuring losses using computational techniques, the study not only fills a significant vacuum in the literature but also offers useful implications for a variety of applications.

The research's conclusions have wide-ranging effects on fields including artificial intelligence integration, flow control, wind energy, and aircraft design. The research sees a bright future for aerodynamics by streamlining energy use, encouraging creative aircraft designs, developing wind energy applications, improving flow control techniques, and using artificial intelligence for real-time optimization. The study's technique, which included theoretical frameworks, thorough analysis of the data, and experiments, greatly advances our grasp of aerodynamic principles. Future developments and improvements in the field of aerodynamics will benefit greatly from this paper's further investigation of the methodology, theoretical background, experimental results, and implications for engineering projects.

Future Work

A big step in reducing large head losses has been made with the modification of a traditional rectangular closed-loop wind tunnel with four corners and a radiator to a modified two-corner (45° each) triangle configuration. Although the 45° corner loses more head than its 90° equivalent, this is offset by the overall decrease in the number of corners. A key factor in maintaining consistent fluid flow, especially at corners, is the thoughtful use of guide vanes, which improves the dependability of test chamber experiments. In addition to addressing the issue of head losses, this creative design emphasizes the significance of geometry and flow uniformity in maximizing the effectiveness and performance of closed-loop wind tunnel systems.

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MANUFACTURING OF LOW-COST WALL PAINT BY THE INCLUSION OF NATURAL WASTE PRODUCTS TO IMPART SUSTAINABILITY

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Abstract

Now a day the cost of paint is high and different variety of paints are required to improve each properties like a water, heat resistance, etc. Also most of the paints contain some toxic chemicals like a lead, etc. These chemicals are producing some ill effects to human beings. Also the recently available paints contain full of chemicals. As an engineer we know all the construction material properties and their tests but we are concentrate less about paints and their tests. So we are planned to prepare a low cost paint with the partial replacement of some natural waste materials like fly ask, polyurethane etc. and we are conduct the experimental tests like a water, heat, chemical resistance etc. as per Indian standard (IS) code provision.

Materials Used

Generally paint contains almost chemical products. In that paint we are using some natural waste materials and which fulfill the property of that chemicals. In which we are studied all the natural wastes and which must be replaceable one. The percentage replacement is taken out from the literature journals.

- Extender - Fly ash (Increases volume)
- Vehicle - Castor oil (Film forming)
- Thinner - Benzene (Dilution)
- Driers - Linoleates (Reduces drying time)
- Plasticizers - Polyurethane (PU) (Elasticity)
- Pigment - Red iron oxide (Colouring agent)

Mechanism and Synthesis of Paint

The mechanism involved in each type of paint depends on the materials may be used as a

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various components of paint. But the used materials should react with one another and to form a homogeneous product.

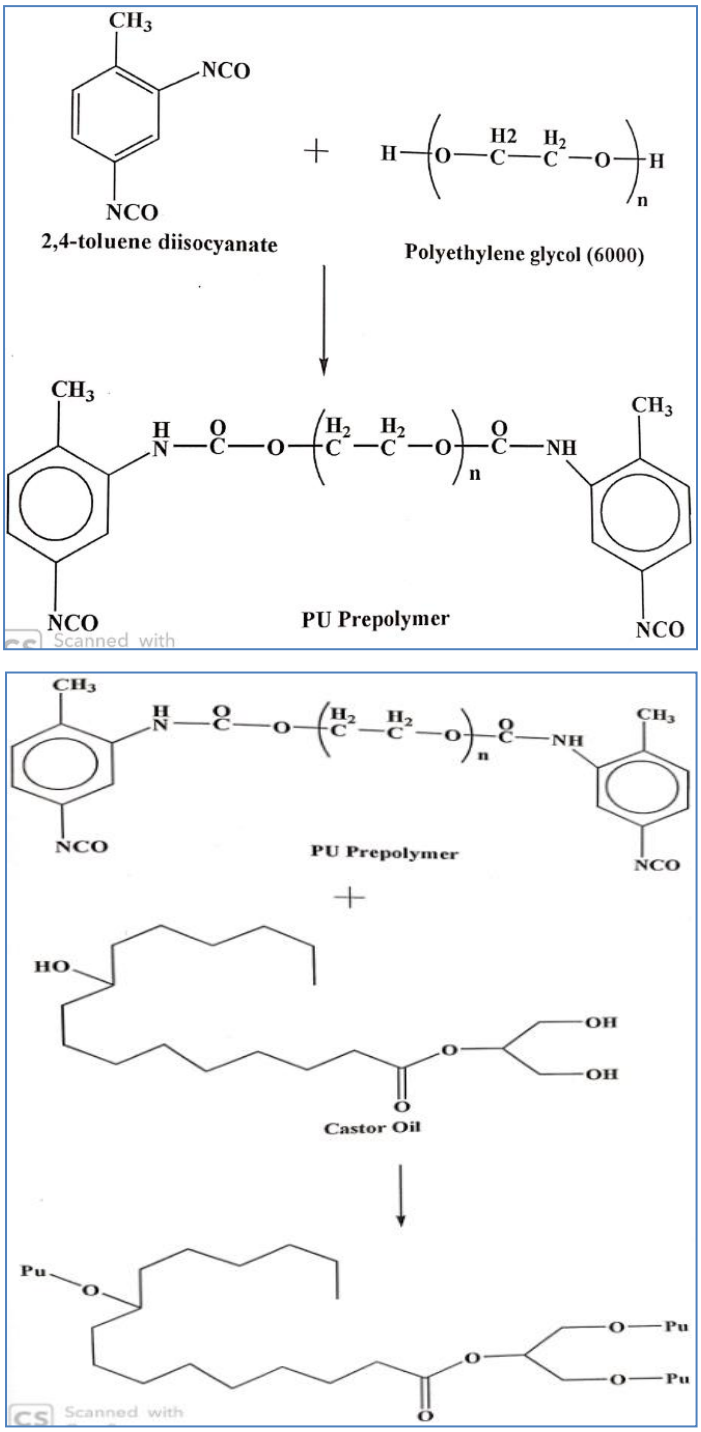


Fig. Synthesis of PU Prepolymer

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Polyurethane prepolymer was prepared by reacting 1.5 equivalent of toluene diisocynate and one equivalent of polyethylene glycol (ppg 6000) in a reaction kettle equipped with thermometer, nitrogen inlet and stirrer. The reaction was carried out at 70°C in N_2 atmosphere and stirrer for 3hours. The temperature was brought down to 40°C and dibutyltin dilaurate catalyst was added and mixed with 30 min. At the end of the time PU prepolymer was collected in a beaker.

Methodology

- Selection of alternative natural waste
- Preparation of mould for specimen
- Preparation of paint
- Preparation of specimen to test paint
- Tests conducted on paint
- Suggestion about paint

Preparation of Specimen and Paint

The specimens prepared as per the Indian standard codes for the preparation of panels and which mention various panels like a steel, timber, mortar, etc. and we are selecting wall paint, so we choose the panel as mortar. The specimen mould is made by wooden frames with an internal size of 5cm x 5cm x 4cm, with top and bottoms are opened and all the four sides are closed. The specimen is made by cement mortar with 1:2 ratio and 0.5 water cement ratio. The size of specimen is 5cm x 5cm x 4cm as per Indian standard (IS 101.1.3).

Quantity of materials required for specimen,

Volume of mortar for one specimen	= 0.05 x 0.05 x 0.04	= 0.0001m^3
Volume of mortar for one specimen	= 40 x 0.0001	= 0.004m^3
Weight of cement mortar required	= volume x density	= 0.004 x 2080 = 8.32 kg
Add 5% as wastage Weight of cement required = 8.73 kg		= 2.9 kg
Weight of sand required	= 5.8 kg	

The specimens which are required for testing are white washed and to make a surface as smooth as possible. After the application of primer coat the specimens are allowed to dry at specified period at room temperature. Now these specimens are ready to acquire a paint film over it.

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Preparation of Paint

Quantity of Materials Required

- Castor oil - 100 gm
- Red iron oxide - 50 gm
- Fly ash - 3 gm
- Polyurethane - 5 gm
- Linoleate - 1 gm

Initially Pigment is mixed with Fly ash by using ultrasonic sound wave water path at a specified period or up to the complete dispersion of both materials. At the end of mixing to obtain a red colour homogeneous compound. Then the castor oil is taken into other beaker and mixed with PU prepolymer by using magnetic stir at a temperature of 70°C. Then both compounds are mixed homogeneously by using ball mill at one day. After that one day period the paint is ready for application over specimen.

Test Conducted on Paint

- Water Resistance Test (IS 101.7.1)
- Salt Water Resistance Test (IS 101.7.2)
- Acid Resistance Test - HNO_3, HCl and H_2SO_4 (IS 101.7.2)
- Heat and Freezing Resistance Test (IS 101.7.3)
- Volatile Matter Test (IS 101.2.2)
- Hardness Test (IS 101.5.1)
- Drying Time Test (IS 101.3.1)

Test Results

	Physical Observation
Water Resistance Test	No colour change, No signs of detoriation, No damage in paint film
Salt Water Resistance Test	Fully and slightly damaged of one and two coated specimens, Salt deposit at the surface, Fully detoriated signs, Slight colour change, Turbid appearance in salt water

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Resistance Test - HNO_3	Colour changed to reddish, Turbid appearance in water, No signs of detoriation, No salt deposition
Acid Resistance Test - HCl	Fully damaged of one and two coated specimens, Salt deposit at the surface, Colour change occurs over the paint film, Fully detoriated signs
Acid Resistance Test - H_2SO_4	No colour change, No signs of detoriation, No damage in paint film, Retain plastic nature of paint film
Heat Resistance Test	No colour change, No signs of detoriation, No damage in paint film, Specimen loss ts temperature within 15 mins
Freezing Resistance Test	No colour change, No signs of detoriation, No damage in paint film
Volatile Matter Test	3.65% < 5% (max)
Hardness Test	Find from Rockwell Scale, 53.66 (two coat) > 40.33 (uncoat)
Drying Time Test	30 to 60 mins

Suggestion about paint from test results

Economically low cost paint prepared by using various alternative natural wastes and that paint are tested against various environmental exposure conditions. The alternative natural waste as fly ash, PU and which fulfill the property of the original chemicals. Instead of lead material, polyurethane is used as a plasticizer. So the harmful effects due to lead are eliminated. Most of the paints are checked against various steel corrosion resistant properties but this paint only checked against aggressive environment as wall paint. Cost of this paint is very low, so this paint is may be used by all the type of peoples.

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Industrial Applications and commercialization

This method can be embraced in the industry because of that inward restoring utilizing pre splashed with naturally accessible waste materials will redress the water scarcity issues.

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A Review Paper on : Image Encryption Algorithms

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Abstract

With the advancements in the world of technology, today's modern world require a strong encryption techniques so as to protect our communication system and process from the intruders. Hence we use different techniques for encryption, in this review study paper we have compared various techniques such as traditional based (Vignere Cipher, RC4,RC5, RC6, DES, AES) based image encryption techniques, Chaos based, quantum and qubit based image encryption methods. We have studied these techniques with the help of different parameters such as entropy measure, NPCR, PSNR and UACI. On comparing these techniques we have identified how with the advancements in technology how the values of these parameters have improved and how strong the encryption has become with time.

Keywords: Traditional based Image Encryption techniques [1-9], Chaos based Image Encryption techniques [11,12], Quantum based Image Encryption techniques [13,14] & Qu-bit based Image Encryption techniques [15,16].

1 Introduction

In the digital era of modern technology, security is a major concern. To protect the data in this technological world we need various different techniques which can help us in encrypting the data and protecting it from the attack of the hackers or the intruders. There are different encryption techniques which are available, as the technology advanced from ancient era to the modern era similarly the encryption techniques have evolved with time.

Different encryption techniques have been consequently advanced by the research scholars in order to develop highly secured security mechanisms which takes care of all the necessary security related parameters and also prevent the system against attacks [10]. Encryption process of an image is that which converts an given image into a form which is unreadable and image is transmitted in such unreadable form through any medium to broadcast. Information in the form of data that we at times transmit through a medium often experience different forms of invasion

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attacks from the hackers or intruders namely Geometrical attack, noise attack, anti occlusion attack, etc. over the transmission channels and at times our data is also changed or replaced, because of these kinds of attacks, there was a need to create a technique or a mechanism that can prevent and resist the effect of these unwnted attacks or the disturbances in the media or data which is transmitted.

An ancient method that has protected the data from decades is the public key cryptographic method, the computers that were used in the ancient times could not efficiently carry out the calculations needed to break it. With the advancement and development of the quantum computers we will be able to solve all the algorithms that are currently helping us to protect the data exceptionally and to a great extend more efficiently. Through these encryption techniques we have developed different security related implications for companies working in almost every field of industry, hence potentially exposing all the data to bring the actors in danger worldwide. In order to make a system or a mechanism secured we need to maintain the confidentiality, authentication and integrity attacks that are a matter of prime concern.

Within this review paper we have compared different encryption techniques by applying them on the set of images. These encryption techniques are represented in form of a flow chart as shown in figure.1. given below

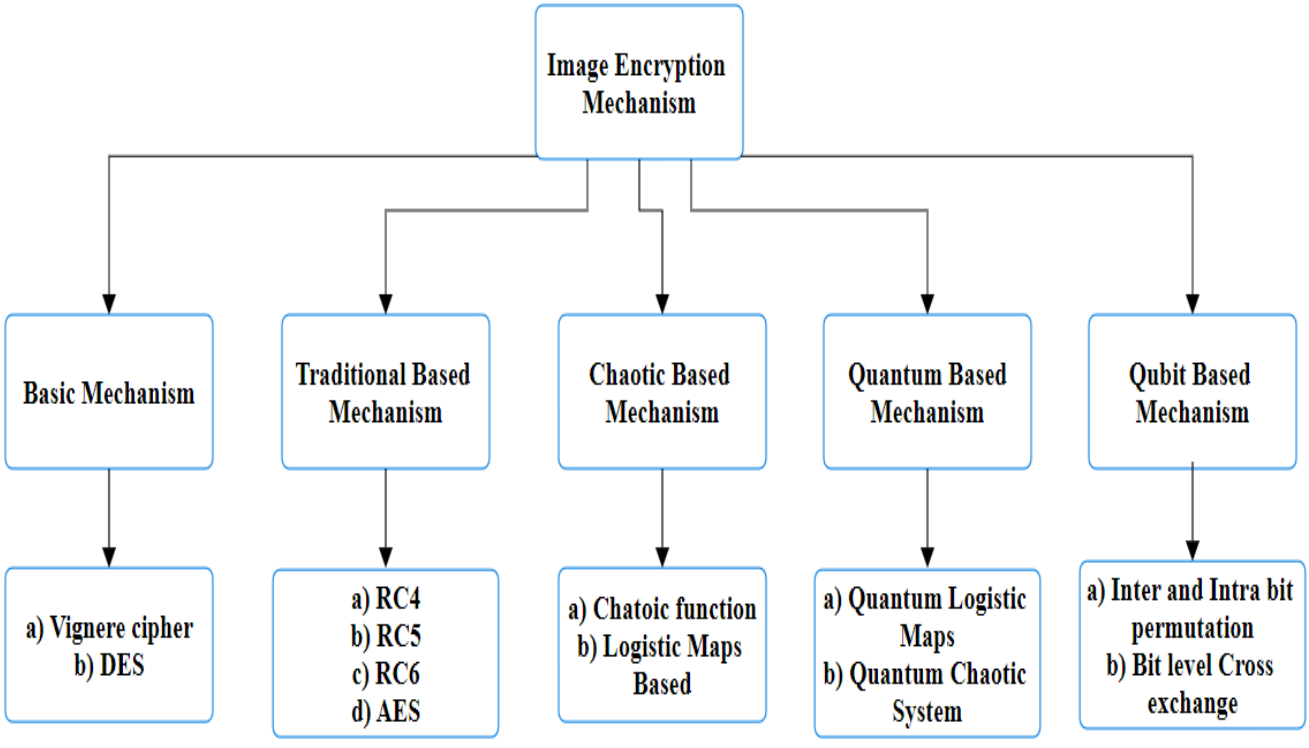


Figure.1. Different Image encryption techniques

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These techniques must have an optimal value of the performance parameters in order to make the system or mechanism highly secure. The value of the parameters leads to the difference between both the images we receive after encryption and the images that we receive after decryption. Most of the journals or work of other researches do not really analyze these techniques or mechanisms on the basis of the parameters that we have mentioned above. Hence, through this review paper we aim the contributions as described below:

- We have analyzed all the techniques present for image encryption (namely- basic, traditional, Chaotic based, Quantum based and Qu-bit based Mechanism) in both the ideal as well as the practical scenarios, in order to bring out the best result.

- We have used various different performance metrices that have been used for the examination of all the various types of examinations to identify the best technique. Security analysis, Robustness analysis (entropy, NPCR, PSNR, UACI, MSE and Bit- error) are executed for comparison.

This entire paper has been organized in a manner that is as follows: Section 2 talks about the motivation as well as the methods adopted and implemented by the different authors of whose we have used the reference, Section 3 mentions the explanation of the entire experimental setup as well as the work done on the various different traditional as well as the modern cryptography techniques, Section 4 talks about the snapshots along with results and discussion after the experiment, Section 5 talks about the conclusions, and Section 6 has the mention of references.

2 Contribution & Motivation

A lot of researcher scholars have given their contribution in the crucial direction of image encryption in order to get best solution for the protection of information and images. A wide variety of survey papers are available in the literature that are based on different image encryption techniques. We have compared different performance parameters in order to compare the performance of these techniques.

Within this paper we have done survey of various different encryption mechanisms like Traditional Mechanism based technique, Chaotic mechanism based technique, Quantum mechanism based technique and Qu-bit mechanism based techniques that are already present in literature, providing a detailed analysis of different parameters which are desirable for the above mentioned encryption schemes.

2.1 Basic Image based Encryption Techniques

Under these we use a basic and straightforward process which use the shifting and substitution process. Using the frequency distribution approach we can easily decode the ciphered data, also the attacks like brute force search attacks, known-plaintext attacks and the chosen plaintext attacks,. Above mentioned techniques were widely used in the early times (in

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the beginning). Brief description of all the basic image based encryption techniques is mentioned below:

- **Vigenere** [1] it is amongst one of the ancient mechanism used for encrypting the alphabets. In this we utilize different cesar cipher techniques to perform encryption. We perform substitution according to the coding given in Vignere cipher table. When we carry out such mechanisms, the cipher text is always present at the intersection of the column of the vignere cipher table, after that there is presence of plain text word or number or special character, further the row is indexed with the help of key message, same we have represented in Figure. 2. This is basic fundamental method to encrypt that can be easily decrypted with the help of frequency distribution. Traditionally the Vigenere-cipher table was used was 26x26 but in the quoted research paper we have studied about the 95x95 vigenere cipher table as shown in Fig.3 . Hence we receive better results.

	PLANTEXT																								
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
A	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
B	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A
C	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B
D	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C
E	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D
F	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E
G	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F
H	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G
I	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H
J	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I
K	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J
L	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K
M	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L
N	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M
O	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N
P	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Q	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
R	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
S	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
T	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
U	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
V	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
W	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
X	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
Y	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Z	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y

KEY

Figure.2. Vigenere Cipher Table 26x26

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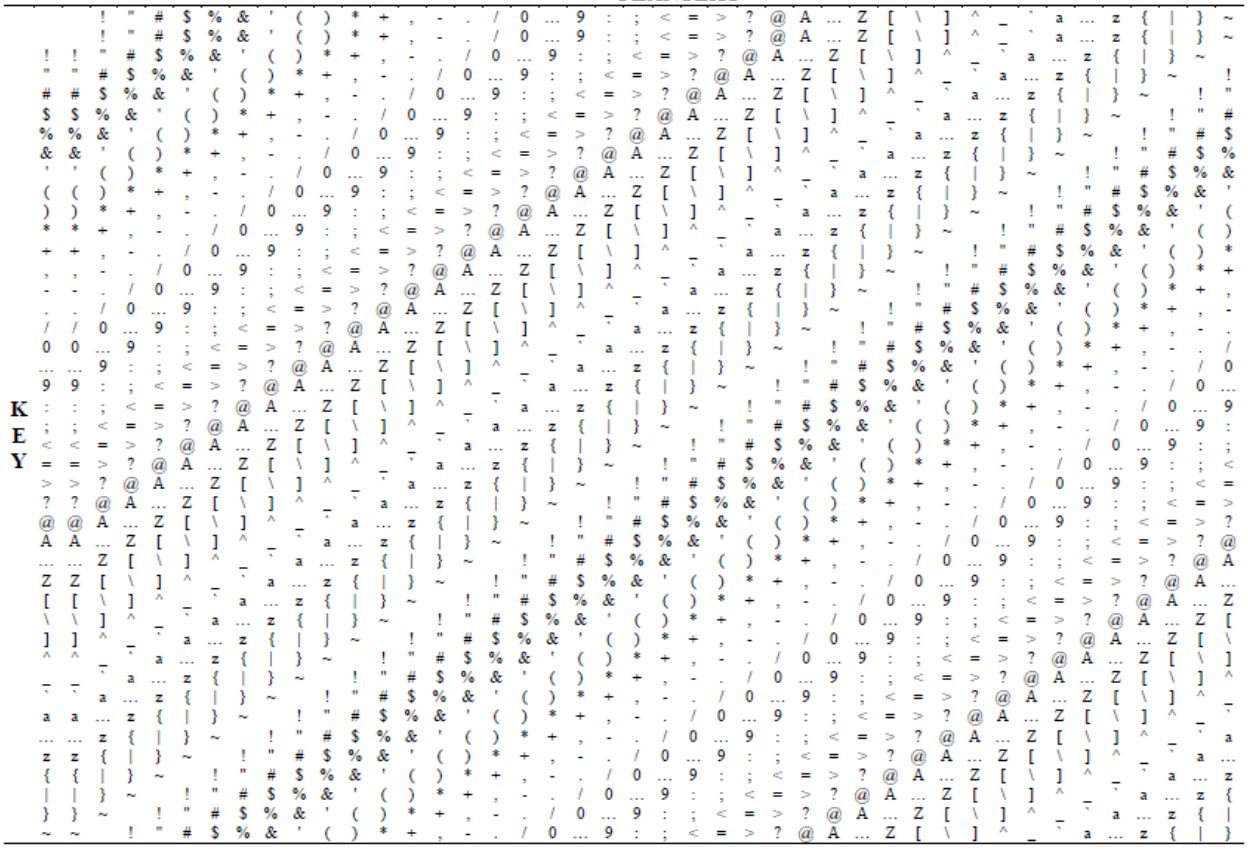


Figure.3. Modified form of Vigenere-Cipher table used for encryption 95x95

- **DES** [2] This encryption mechanism means data encryption standard technique [2] which was developed by IBM company and later on was declared as an official technique by National Bureau of Standards [3,4]. This is amongst one of the very first symmetric key based block cipher-text encryption technique which is dependent upon Feistel-Cipher technique. In this technique we use a 64 bits block-data as well as a key of 64 bits, that is then made to pass via 16 complete rounds. The technique of encryption through DES depends on these two following attributes: substitution followed by Transposition, that includes complete 16 steps, that is termed as. This entire process of encrypting consist of a round table function, followed by a key schedule, then we perform the initial and then we apply final permutation procedure in order to receive a 64-bit encrypted data. In the process of encryption through DES we apply a very high number of continuous forward as well as reverse procedure, in spite of this still, the security mechanism of DES can be easily broken with the help of many different methods. Among them the attacks like Brute force search attacks and known attack of plaintext attack are amongst the most commonly used methods to decrypt this DES mechanism of encryption.
- **TDES** [5] The Full form of this technique is the "Triple Data Encryption Algorithm" [5]. This technique is also a symmetric key based block cipher technique which utilizes the encryption algorithm based on DES mechanism three times. TDES utilizes 3 alternative

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ways to select the keys. In this technique the user has to initially generate and then distribute the keys, that always includes 3 keys that are always different. In TDES mechanism wwe have to first Encrypt the data block by using the DES algorithm that is done by the help of first key, after that we perform decryption of the previous step and finally we proceed to produce the output by making the use of DES and the 2nd key that we generated. Then we follow the process of doing the encryption of the output that we produces in the previous steps by making the use of DES algorithm as well as the 3rd key. This can be vulnerable to a man who is present in middle attack who also tries to block the collision attack.

2.2 Traditional based image encryption mechanism

- **RC-4** [6] This type of encryption mechanism is basically a stream based cipher and follows a algorithm which is based on key which is of variable-length. Using RC4 encryption technique we can easily encrypt only a single byte at a particular time (or at a time larger units too). There is a pseudorandom generator which is used to generate a 8 bit input number which is based on key key based input and this has to be unpredictable which has no knowledge about the input key, then the output of this generator is known as the key-stream, we then combine the single byte at a particular time along with plain-text stream cipher by applying the X-OR operation. In this work which we have cited above a fresh new method that is used for encrypting the image that is based on the modified form of RC-4 stream based cipher algorithm is proposed, in this the author has scrambled the pixels of the image before the application of the XOR based encryption operation. Then the author has compared performance parameters of proposed method by the wuthor which is the modified RC-4 based algorithm with standard RC-4 algorithm in which we analyze the histogram, perform the calculation of the correlation coefficient among the pixels that are adjacent to each other, and finally measured the information entropy. Finally the results demonstrated that algorithm that is proposed out-performs the algorithm which was based on standard RC-4 mechanism in-terms of resistance towards the statistical attacks.

- **RC-5** [7] This technique is a successor of the algorithm discussed in [6], in this we have used the left side rotation as well as the right side rotation, these two are dependent on the data. This type of encryption technique is although fast and quite straightforward technieque based on symmetric key block. It this plaintext can be of variable length, in this we perform a number of rounds, key of 8 bit bytes. Every round has the inclusion of operations like bitwise X-OR operation, followed by the circular shift, and also additionally many other operations. To make this mechanism more secured, it is always suggested to always have a set of 18–20 rounds during the encryption process. By using the input of 64 bits followed by the 12 rounds in this process of encryption, this RC5 based mechanism is then decrypted by making the use of a differential attack along with the help of 244 chosen plaintexts.

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- **RC-6** [8**]** This type of encryption technique is based on symmetric key-block ciphers, it ia also a successor of the previously used techniques namely RC-4 [6] & RC-5 [7] algorithms. We can now view this as the two parallel RC5 procedures that we have performed side by side. In this technique we use 128, 192, or 256 bit of keys as well as a block of 128 bits. There is a single difference among the RC-5 and RC-6 techniques which is, RC-6 utilizes 4 w bits of word registers, on the other hand RC-5 utilizes only 2 w bits of register. None of the practical attacks can easily break the RC-6 algorithm within a reasonable time.
- **AES** [9] This encryption technique refers to "Advanced Encryption Standard" [9]. This is based on symmetric key mechanisms which was declared officially by National Institute of Standards and Technology. It utilizes 128 bits of input text or media as well as the varying key size like 128, 192, 256 bit [10]. AES mechanism has a very great growth in the field of security. In this AES mechanism we have used a series of inter-linked operations, that involves the procedure of substitutions as well as the permutations. In AES the entire encryption procedure includes the process of substitution at the byte level, that replaces the value by using the s-box. After that we perform the shift operation which we use to change the position which is then followed by the mixing of the columns, we also use the special mathe-matical functions in order to create a new form of matrix. After that we add a round key, in this process in which we X-Rr the data with the 128-bits round keys to get the cipher-text as the result.

2.3 Chaotic based image encryption mechanism

With the advancements in the field of parallel processing of data, it required an enhanced encryption mechanism in order to overcome and develop a mechanism that can perform the processing at a high speed. To search and develop such mechanism, the researchers transformed and moved towards the mechanisms that will be based on chaotic based techniques. With in these mechanisms we use different type of chaotic maps, that already possesses chaotic behavior. All these maps always provide drastic changes in the inputs with a very slight change in the information. Chaotic map is widely used within the encryption mechanisms to ensure high security. On the other hand, chaotic based techniques always work in two phases; first phase is confusion phase, in this we shuffle pixels of the image, second phase is diffusion phase, in this we alter values of the pixels. A slight brief of different chaotic based image encryption techniques is mentioned below.

- **1st Chaos** [11] This technique was proposed by Al-Maadeed**,** in this author has mentioned about an unique approach in which he has proposed a mechanism for image encryption that is purely based on the Lorenz chaotic map system, it also makes the use of primitive non-reducible polynomial based S-boxes. Author has defined the experimental setup in the form such that initially 16 different S-boxes which are dependent on the projective linear general group are defined, thereafter 16 primitive non-reducible polynomials of Galois field of the order of 256 X 256 is defined, after that we utilize these S-boxes along with the combo of the chaotic maps under the image encryption mechanism. 3 different chaotic sequences are produced with the help of Lorenz chaotic system corresponding to the respective variables x, y and z. After that we construct a new chaotic sequence which is

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pseudo random ki based on x, y and z. At last the plain image is encrypted with the help of chaotic sequence ki along with the XOR operation in order to generate a ciphered image.

- **2nd Chaos** [12] This research work was proposed by Hanchinamani, this work is based upon Peter de Jong map as well as the RC-4 stream cipher. The Peter De Jong chaotic map is helpful in finding the initial key that will be used in RC-4, this algorithm is then utilized in the generation of the pseudo-random numbers that will be further used to rotate and then diffuse the values of the pixels of the image. During the stage in which we perform the permutation, the pixel values are rotated, then we perform the diffusion process to complete the encryption round. We perform the permutation of pixel values in two stages: initially, the rows and columns positions are made to scramble circularly in an alternative orientation. Then, we rotate all the pixels of the image in a circular manner using the pseudo-random numbers. This diffusion process of the pixel is performed in two orientations, first one is the row wise in the alternate manner and column-wise in the alternate manner, further implementing forward diffusion as well as the backward diffusion process in each of these steps in order to generate an encrypted image.

2.4 Quantum based image encryption mechanism

- **1st Quantum** [13], In this mechanism author has defined a novel algo of the image encryption which is dependent upon the quantum chaos. We produce key streams using 2D logistic map which are kept as the initial conditions as well as the parameters. Arnold scrambling algo which we are using here is exploiting the permutation of the pixels of image color components by using the keys. During the process of diffusion, we introduce a new mechanism of encryption, that involves folding, is proposed in order to alter the values of the diffused pixels. In order to get high level of randomness as well as the complexity, the 2D-logistic maps and quantum chaotic maps are included along with the help of nearest-neighboring coupled quantum chaotic based lattices.
- **2nd Quantum** [14], Here proposer has proposed an image encryption scheme for the colored images that completely depends upon quantum chaotic system. Firstly, a fresh substitution scheme is used that is dependent on total auto morphism in the integer wavelet in which we change it by scrambling just the Y (Luminance) component that lies in the low-frequency sub-band. Generally the 2 diffusion modules are accomplished by modifying the properties of horizontal and vertical neighboring pixel of the image along with the help of the adopted quantum based chaotic map mechanism. Lastly, we apply the confusion and substitution in order to create an intermediate key stream of a chaotic based image with the help of an image encryption mechanism based on quantum chaotic system.

2.5 Qubit based image encryption mechanism

- **1st Qubit** [15], This research is given by Ms.Manju Kumari, here the author has used an encryption process that is dependent on the keys. These generation of the keys is done with the help of quantum chaotic maps. Entire process of image

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encryption is carried out in 2 steps which are, first is the confusion process and diffusion process also the keys were required that are used during the performance of the 2 processes. We make the use of Electronic code book in order to carry out the encryption process, to perform the initial permutations, we carry out bit plane scrambling along with the inter-bit plane scrambling and the process of confusion along with the eight directional folding process is used to carry out the diffusion process.

- **2nd Qubit** [16], This research piece was defined by Nanrun Zhou, in this the author has defined an encryption mechanism that is helpful in creating a bit-level encrypted image. This system is basically dependent uponcv5D hyper chaotic mechanism as well as the mechanism that performs the quantum cross-exchange operations. In order to bring improvement in the scrambling effects, swapping process in the quantum channel is used. This proposed color image based encryption encryption has bigger value of keyspace as well as the high quality of security since it uses 5D hyper-chaotic mechanism which already has a very complex behavior along with it, it has preferable randomness in the system, and above all it is unpredictable over those techniques that are mostly dependent on the other low dimension mechanisms that are based on hyper-chaotic techniques.

In the above section we have mentioned numerous different image encryption techniques readily present in the given literature which we will now compare on the basis of different metrics and parameters that decides the performance of the above mentioned techniques. All results along with their initial values of the parameters are mentioned below.

4 Setup to perform the Experiment

Below we have defined Table 1 in which we have depicted parameters that are required for the simulation setup, this will be used as sample in order to carry out experiments. Complete report of the analysis of the different image encryption mechanisms is applied over the images of size 256 X 256. Here we have used the images with ".jpeg" extension which belongs to the category of RGB as well as Gray images. Complete procedure is carried out in a laptop having 2.50 GHz Intel Core i7 processor and the operating system of Windows 10 Pro. Google Colab 2023 for Python Simulation is utilized for the compilation of different result that we have mentioned under in Section-6.

Table 1 Experimental Setup Parameters

Processor	2.50 GHz , i7 Processor
Operating Syetem	Windows 10 Pro
Image Type	Jpg
Simulation Tool	Google Colab (Python Programming Language)
Image Size	256*256
Colour Type	RGB Images and Gray Images
Keys	**Vignere** {3b6@#142936a$%d2a6*^7157609cf4f2d}

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DES {354456688ABCDFF1}

TDES {240468899bbcdff06bbcdff00774566933457799bbcdff11}

RC-4 {c4f5fc9107617fba6a1dea826151e7b22b7f151628bed2a6abf7158809cf4f3c}

RC-5 {926f5719be52c3517365a50210a9ce92}

RC-6 {fe48a2fd9402d8efe613f1b6cc773aag}

AES {0e2681e958e9e6590cb7aff6ad7d6697}

1st Chaos {a=10, b=28, c= 8/3}

2nd Chaos {μ=0.8127, ×0=0.1318, y0=0.4137}

1st Quantum {206 22 43 62,121,202 96 75,102 6 8,251,138 29 97 27}

2nd Quantum {Qo(1)= 0.463442477, Qo(2)= 0.0045325, Qo(3)= 0.0021364 Qo*(1) = 0.00197, Qo*(3)= 0.00388, β= 4.499, λ=3.999}

1st Qubit {Qubit 2{seed1=[0.51; 0.52; 0.53; 0.6; 0.37; 0.46; 0.38; 0.61], seed2=0.49}

2nd Qubit {Qubit 1{a=10, b=8/3, c=28, p=1.3, q=2.5, ×1 (0)= 0.3252, ×2(0)= 0.4761, ×3 (0)= 1.2561, ×4 (0) = 0.6281, ×5 (0)=1.5}

5 Result

We have analyzed all results after calculating the average value of all the values we have recorded of the images of the sizes 256 X 256. We have used ".jpeg" extension image in order to carry out the experiment.

5.1 Assessment of visual images

Table 2 depicts the original images and the encrypted images that we get after the implementation of the encryption techniques on a ".jpeg" image of 256 X 256 size. We have also illustrated the visual evaluation of encrypted images that we receive after the successful application of various encryption algorithms. We can easily observe here chaos based mechanism, quantum based and qubit based mechanisms have a very high scrambling value of the original image of the encrypted image, further there is none info about the original image that can be easily bought from the encrypted images. The reason behind this it simple, that is to sensitive behavior of Chaos based mechanism, Quantum based mechanism and Qubit based mechanism by using conditions initially. Further more, these images that we have after the encryption we get the basic and traditional mechanisms which give altogether different type of scrambling. Encrypted images received after applying the Vigene're mechanism and the mechanism based on the fractal mechanism covers a good info regarding original image, it can not be considered as productive on the visual grounds. Lastly, each and every mechanism produces decrypted images that are similar to the original image we can also find reliability of unscrambled image if the security of the complete mechanism is guaranteed.

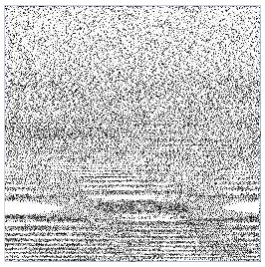
Table 2 Assessment of visual images 256 X 256

Technique Name	Unencrypted Image before encryption	Image after the encryption

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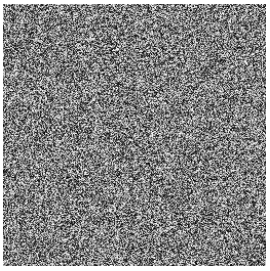
Vignere





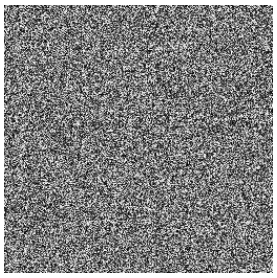
DES





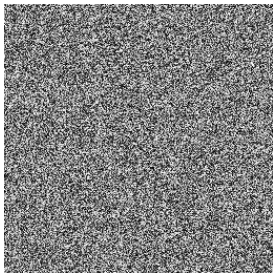
TDES





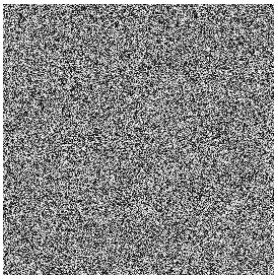
RC-4





RC-5

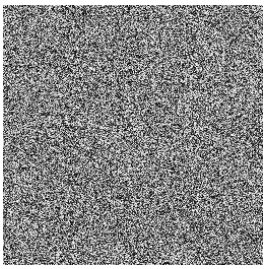




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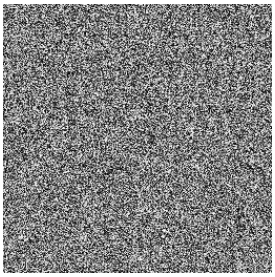
RC-6





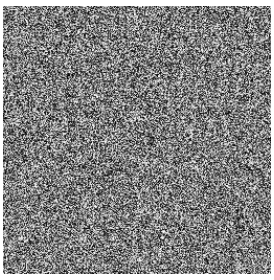
AES





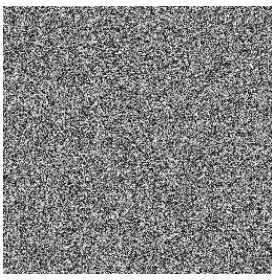
1st Chaos





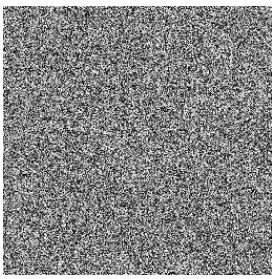
2nd Chaos





1st Quantum

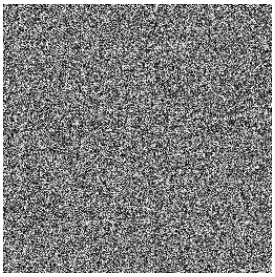




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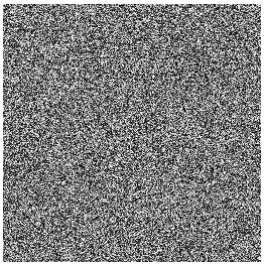
2nd Quantum





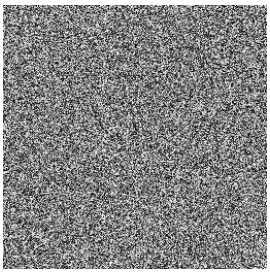
1st Qubit





2nd Qubit





5.2 NPCR (Net pixel change ratio), It refers to rate of change in the number of pixels of an encrypted image when we only disturb first and the pixel that we have disturbed, further we have compared the plain image with the image that we have disturbed [19]. Assume C1 and C2 as encoded image for first and plain image with changed pixel respectively. Thus, NPCR is given by the following eqn:

$$\mathrm{NPCR} = \frac{\sum_{i=1}^{H}\sum_{j=1}^{W} D(i,j)}{W*H} *100\%$$

Here, H as well as W refers to height and width of image. D is defined as:

$$\mathrm{D(i,j)} = \begin{cases} 0 & C1(i,j) = C2(i,j), \\ 1 & C1(i,j) \neq C2(i,j) \end{cases}$$

Table 3 Result of NPCR Test

256 X 256 Image	Theoretical NPCR value			
	Values Reported	$N_{50\%}$= 99.5794%	$N_{10\%}$= 99.5638%	$N_{1\%}$= 99.5442%
Techniques	Values Reported (in %)	50% Level	10% Level	1% Level
Vignere Ciphere	6.26	No	No	No

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DES	99.5713	Yes	Yes	Yes
TDES	99.5764	Yes	Yes	Yes
RC-4	99.6334	Yes	Yes	Yes
RC-5	99.5911	Yes	Yes	Yes
RC-6	99.6017	Yes	Yes	Yes
AES	99.6127	Yes	Yes	Yes
1st Chaos	99.6282	Yes	Yes	Yes
2nd Chaos	99.6346	Yes	Yes	Yes
1st Quantum	99.5988	Yes	Yes	Yes
2nd Quantum	99.5514	Yes	Yes	Yes
1st Qubit	99.6122	No	No	No
2nd Qubit	51.2349	No	No	No

5.2 Unified Average Change in Intensity (UACI), It refers to the difference between the average value of intensity between the plain and encrypted images [19]. It is given as:

$$\mathrm{UACI} = \frac{1}{W*H}\left[\sum_{i=1}^{H}\sum_{j=1}^{W}\frac{|C1(i,j)-C2(i,j)|}{2^{L}-1}\right]*100\%$$

Here, L is defined as number of bits depicting the channels red, green and blue respectively. Now we can observe that, for every change in the value of pixel in these Chaos techniques, the NPCR as well as the UACI values have passed for every 4 test set of the pictures which are around 99.49% as well as 33.35% individually. The values of such qualities are very high, thus leading to a direct resulting diffusion stage that is present within these mechanisms. These stages provides a guarantee about the changes in scrambled images instead of single pixel that is present in the original image which is changed. Thus, making the chaos based mechanism and quantum chaos based mechanism excessively resistive towards these differential attacks. If there is change in the value of single pixel, the ordinary cryptography conspires, a very less value of NPCR and UACI qualities. Techniques such as Vigene're ciphere, Visual as well as the RC-4 provides least values of NPCR & UACI between the mechanisms that we have utilized here. Thus, here we have successfully demonstrated the helplessness of such techniques against these differential attacks. Now mechanisms such as RC-6 as well as the AES has demonstrated the most appropriate values of NPCR and UACI parameters as compared to other conventional techniques. NPCR and UACI values were higher for these mechanisms, where the UACI values expands in the excess of multiple times than the past referenced mechanisms. Hence, we can say that, all of these parameter refers to the qualities that are together higher as compared to the qualities acquired by the disordered plans. It obviously demonstrates that these conventional techniques are not especially viable against the differential attacks. Also, as soon as the size of expands increases, there is a decrease in the values that can be observed showing an expansion in powerlessness with size. On getting the high values of the parameters like NPCR and UACI, they now standout from the race of most of the significant security criteria. Numerous scientists have utilized the subjection of

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calculations giving lower estimations of these parameters for cryptanalysis [17, 18]. Tables 3 and 4 show the NPCR and UACI test results for 256 X 256 images for different encryption mechanisms stating which mechanisms either it pass or fail in qualifying the 50% level, 10% level and 1% level of the experimental investigation. Thus, represented in table the Vigenere ciphere, 1st Qubit, 1st Quantum based mechanisms don't pass either of these tests for NPCR and UACI paramaters.

Table 4 Result of UACI Test

256 X 256 Image	Theoretical UACI value			
		$U^-_{50\%}$=33.2941%	$U^-_{10\%}$=33.2356%	$U^-_{1\%}$=33.1695%
		$U^+_{50\%}$=33.6548%	$U^+_{10\%}$=33.7027%	$U^+_{1\%}$=33.7878%
Techniques	Values reported (in %)	50% Level	10% Level	1% Level
Vignere Ciphere	5.2910	No	No	No
DES	33.5061	Yes	Yes	Yes
TDES	33.3344	Yes	Yes	Yes
RC-4	33.4643	Yes	Yes	Yes
RC-5	33.3008	Yes	Yes	Yes
RC-6	33.5203	Yes	Yes	Yes
AES	33.4216	Yes	Yes	Yes
1st Chaos	33.4688	Yes	Yes	Yes
2nd Chaos	33.5468	Yes	Yes	Yes
1st Quantum	33.5638	Yes	Yes	Yes
2nd Quantum	33.4612	Yes	Yes	Yes
1st Qubit	33.4942	Yes	Yes	Yes
2nd Qubit	33.4674	Yes	Yes	Yes

Table 5 Result of Analysis of Key Space

Techniques	**Key Space**
Vignere Ciphere	2^{128}
DES	2^{56}
TDES	2^{168}
RC-4	2^{256}
RC-5	2^{128}
RC-6	2^{128}
AES	2^{128}
1st Chaos	2^{192}
2nd Chaos	2^{384}
1st Quantum	2^{128}
2nd Quantum	2^{224}
1st Qubit	2^{432}
2nd Qubit	10^{72}

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5.3 Peak signal to noise ratio (PSNR), in terms of mathematics we can define it as:

$$\text{PSNR} = 20*\log_{10}\left(\frac{255}{\sqrt{MSE}}\right)db$$

PSNR is ratio of the most extreme power part of the signal to the noise present in it. MSE is the mean square error, also known as a risk function. MSE [20] is given as:

$$\text{MSE} = \frac{1}{W*H}\left[\sum_{i=1}^{H}\sum_{j=1}^{W}\left[O(i,j)-E(i,j)\right]\right]^2$$

Here, O as well as E depicts the value of pixels of original as well as the image received after the encryption, (i,j) depicts location of the pixels. Below in table 6 we have demonstrated average value of PSNR that can be acquired by 1000's of images as well as the standard deviation values of all mechanisms readily present in literature. Each of the plan used has been practically compared to the estimated values of PSNR except the Hierarchal Visual Techniques, representing the least PSNR value among all of them. RC4, RC5, RC6, TDES, Visual represents the highest values of PSNR.

Table 6 Result of values of PSNR with Deviation from standard values (SD) for different mechanisms readily present in literature

Techniques	Values of PSNR	Deviation from standard values
Vignere Ciphere	26.52138	0.032918
DES	26.62319	0.025487
TDES	27.13095	0.036141
RC-4	27.20161	0.046889
RC-5	27.1773	0.0411186
RC-6	27.32	0.0807903347
AES	27.17485	0.0415306
1st Chaos	27.18469	0.080029
2nd Chaos	27.27153	0.0954008
1st Quantum	27.21794	0.0677458
2nd Quantum	27.11598	0.0800618
1st Qubit	27.7531	1.200765
2nd Qubit	27.16553	0.357861402

5.4 Information entropy, Above in Table 6 we have analyzed about the values of information entropy along with their values in respect to the standard deviation available for different mechanisms that are readily present in the given literature. Each mechanism for the image based encryption provides the values of entropy which is approximately near to perfect estimated value of 8. Table 7 depicts different values of entropy in comparison to the values of standard deviation derived from these encrypted images. We can derive from these results that the average value of entropy for mostly all the techniques readily present

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in literature is nearly close to 8. Chaos based mechanism, quantum based mechanism and qubit based mechanisms give high value of entropy that is very close to 8.

Bit Error Rate (BER), we describe BER as probability of error as long as number of incorrect bits are transmitted per unit time. We obtain BER after dividing number of incorrect bits with absolute number of bits that are to be transmitted. Unless and until a computerized transmission of info takes place over corresponding channel, the modification in the bits may happen only due to the presence of noise in the channel or the interference. Hence, in such a

situation it is necessary to make the calculation of BER. The value of BER many a times also gets increased with declination in quality of the channel.

$$\mathrm{BER} = \frac{1}{\mathrm{W*H}} \left[\sum_{i=1}^{H} \sum_{j=1}^{W} \left[O(i,j) - D(i,j) \right] \right]^2$$

here O and D refers to the pixel value of an original image as well as the decrypted image and (i,j) depicts the location of the pixels. Low value of BER depicts that when the encrypted image is made to transmitted through the noisy channel, the particular technique is able to retrieve a good amount of info whereas on the other hand high value of BER represents that particular technique has failed to retrieve even little bit of the information.

Table 7 Values of Entropy with deviation from standard values of different mechanisms readily present in the referenced literature

Techniques	Values of Entropy	Deviation from standard values
Vignere Ciphere	7.740797	0.0241609
DES	7.978028	0.0176982
TDES	7.960145	0.0282654
RC-4	7.9745898	0.0242307
RC-5	7.957616	0.021149
RC-6	7.957755	0.021579
AES	7.98614	0.002888
1st Chaos	7.985027	0.000724
2nd Chaos	7.962831	0.000903
1st Quantum	7.985556	0.152205
2nd Quantum	7.983825	0.002196
1st Qubit	7.999009	0.00011
2nd Qubit	7.974637	0.151696177

Conclusions

In order to create and look for highly secured mechanisms for encryption, we need to study and look on to a wide variety of encryption mechanisms that were already proposed as well implemented and their results are available for the reference. In this piece of review-paper we

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have discussed about the different types of image encryption techniques that are as follows: basic images encryption based mechanism, traditional images encryption based mechanism, chaotic images encryption based mechanism, quantum images encryption based mechanism and qu-bit based images encryption based mechanism methods, which we have implemented using the Google Colab 2023 (Python Programming Language). On carrying out the complete assessment of different mechanisms for image size 256 X 256, we compiled the results and calculated the values of different performance parameters along with the values of the standard deviation for every performance metric for ideal and the practical scenario, thus we reach out to the following points:

- Chaos as well as the quantum based image encryption mechanisms provides us larger amount of resultant images that are visually scrambled. We achieved this due to the encryption process being carried out in 2 phases. First we are carrying out the confusion phase and then we are carrying out the diffusion phase. This leads in getting high amount of the change in the values of pixels.
- Quantum as well as the chaos-based image encryption mechanisms have higher resistance in front of the differential attacks due to the presence of high key change sensitivity that is highly sensitive towards the initial value. None of the ancient traditional schemes was used there for images dedicatedly, thus it offered low sensitivities towards the initial value of keys or an image, hence resulting towards very low resistance towards these differential attacks. We are able to achieve this because of key generation with the help of chaotic maps. Maps that we use with such schemes are extremely sensitive towards the initial conditions because of which when we change even a single bit, there is a very big change in the resulting data of the encryption.
- Chaos based image encryption mechanism, Quantum based image encryption mechanism, and qubit based image encryption mechanism, all three can easily resist the known plaintext attack as well as the chosen-plaintext attack. We can achieve this with the help of the maps that are basically used in mechanism to generate the key values. These mechanisms are generally sensitive towards the initial conditions, when we change even a single bit present in data, this always leads to the change in data received after the encryption. So, it is quite impossible that we can generate an accurate key or regenerate an original data even when intruder or the attacker knows the cipher text.
- Time to consume is an important factor which is considered to access a performance of any encryption scheme. Traditional based image encryption mechanisms such as AES and RC4 as well as the chaos based image encryption scheme, quantum based image encryption scheme as well as the Fractal based image encryption schemes, all show less time complexity. Thus, it is a strict constraint of time.
- Few of the traditional based image encryption schemes also result towards good inferences of PSNR as well as BER. On the other hand RC4 & Vigenere ciphere are among those techniques. 2nd Quantum fetches us higher value of PSNR and a lower value of BER in comparison to the other mechanisms; thus, showing that even after having a noise in the transmission channel, mechanisms having a lower value of BER can easily decrypt the information. These mechanisms thus can make assurance of the security of the information in both the ideal as well as the practical scenario.

We can say that with time the technology has advanced and as the technology has advanced so has the encryption techniques have developed better and provide more secured system for encryption and security of the data.

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ISFT AM 09
The Development and Characterization of Dual Metal Reinforced Polymer Composite Materials for Fused Deposition Modeling

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Keywords: Fused Deposition Modelling, Melt Flow Rates, Viscosity, Acrylonitrile Butadiene Styrene (ABS) composites, Izod Test, Hardness

Abstract

Much study has recently been done on the integration of micro-sized components into polymer melts to improve the mechanical properties of polymer composites and get the necessary processability for Fused Deposition Modeling (FDM) in 3D printing. This study aims to investigate the processability of the proposed material by experimental 3D printing and mechanical characterization. We created material compositions employing a dual metal filler of titanium and tungsten, and we manufactured them using a solvent dissolving approach. In this investigation, we employed dual metal filler ABS (Acrylonitrile Butadiene Styrene), which is micro-sized (average 50 microns), in 3D printing to create fused filaments. We also looked at the dual metal powder compositions' Melt Flow Rates (MFR) at weight (gram) percentages of 2.5%, 5%, 7.5%, and 10%. It has been shown that while MFR rises with increasing infill percentages, voids also become more noticeable, which leads to the finding of improved 5% compositions. We looked closely at the filament and 3D-printed component morphology. It has been observed that during printing of sheet few voids appears inside the layers of lamination. It has been found that when dual metal fillers are loaded into created ABS composites, the impact strength decreases, but the shore D hardness value continues to rise.

Introduction

Printing composites frequently use fibers, nanomaterials, and particles as reinforcement. Recently, 3D printing has received a lot of attention. Fabricated parts are mostly used for design

verification, functional testing, medical applications, and patterns for casting processes [1-4]. FDM systems can process parts in a variety of engineering plastics such as ABS, polycarbonate (PC), and mixes of ABS and PC. Because it can build objects layer by layer with acceptable geometric precision [5], it has been around for years. Fused Deposition is one of the frequently employed techniques. Numerous researches have been written about creating composites via 3D printing by adding reinforcements to the polymer melt. A popular rapid prototyping method, Fused Deposition Modelling (FDM), was created by Stratasys Inc. Traditionally, the FDM systems could only produce parts in thermoplastics and waxes. The extruded material is deposited layer by layer through a nozzle while being fed feedstock filaments from a spool [6]. As can be seen in **Figure** 1, the fundamental workings of the FDM process give significant potential for a variety of different materials, such as metals and composites, to be created and employed in the FDM process. The most prevalent nanoparticles are carbon nanotubes [7], graphene [8], graphite [9], and ceramic nanoparticles utilized in this manner [10]. Weng et al. used organically modified montmorillonite (OMMT) to print acrylonitrile butadiene styrene (ABS) nanocomposites, and the inclusion of 5 wt% OMMT increased the tensile strength of 3D printed ABS samples by 43%, because of its simple operation and great material utilization, filament fabrication (FFF) [2]. FFF 3D printed products have a wide range of applications, including the aerospace [11] and construction sectors [12], as well as the disciplines of art and education [13] and medicine [14,15]. However, the mechanical strength of the majority of 3D-printed polymer goods limits their industrial application. The first innovative metallic and ceramic-based materials for the FDM technique for rapid production of functional components with superior mechanical properties were created by researchers at Rutgers University [16,17]. For structural and bio ceramic applications, they have used the method to produce functional pieces from a variety of materials, including silicon nitride, aluminums oxide, hydroxyapatite, lead-zirconium titanate (PZT), lead-magnesium niobate (PMN), and stainless steel. The metal/ceramic powders were combined with an organic binder system to manufacture these components on the FDM system. The characteristics of the mixed feedstock filament satisfy the requirements for viscosity, flexibility, and stiffness for successful FDM processing.

Very few literatures, have reported the investigation of dual metal-filled polymer

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composites. In this paper, the findings of the mechanical property and printability with 3D printer, of ABS- Titanium Dioxide and Tungsten (ABS/TiO_2W) filled composite polymer is presented.

The perspective of wider scope for the application of ABS- Titanium Dioxide and Tungsten (ABS/TiO_2W) filled composites in the area of bio-compatible, automobile component parts materials. The filler Tungsten is preferred as it enhances the microhardness erosion resistance of polymers. The modeling of ABS-Titanium Dioxide and Tungsten (ABS/TiO_2W) composites with additions of titanium and tungsten in 2.5%, 5%, 7.5%, and 10% of weight(grams) percent each have been examined.

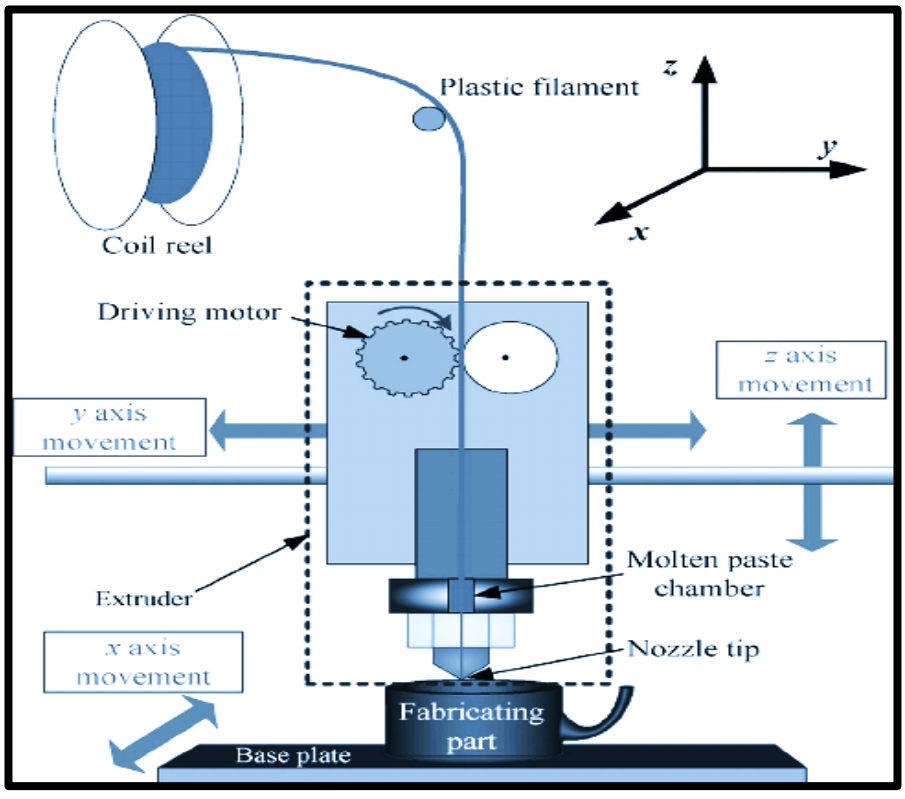


Figure 1 3D Printing Fused Deposition Methodology process

2. Experimental

2.1. Material

Materials acquired from supplier PLASTIC SALES(India), market in Mumbai, Acrylonitrile Butadiene Styrene (ABS) in a pallet form with a mean diameter of roughly 2.5mm. It is natural white pure virgin ABS in pallet form. It weighs 1090 kg per m^3. Approximately 50

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micron-sized spherical powders of TiO_2 (titanium) and W (tungsten) have been employed as metal filler materials. which came from Mumbai's Parshwamini Metals. Acetone is a lab-grade dissolving solvent that is utilized. They were supplied by the Mumbai Institute of Chemical Technology.

2.2 Sample Preparation

The most popular approach for creating polymer composites is the melt intercalation technique. Property solvent/non-solvent techniques are a good option due to polymers' thermal breakdown [18]. During that precipitation, there was frequently a scenario of changing compositions. Consequently, mechanical mixing procedures came next. A similar technique has been used by Matthew et al. to produce ABS-SS composites [19]. In this research, solvent technologies have been used to create a new ABS dual metal fillers composite. Weighted quantities of ABS pallets were first dried completely in the oven for 3 hours, to get completely moisture free pallets. Following drying, these ABS pellets are dissolved, with lab-grade acetone, and kept for 48 hours, to get completely dissolve solution of ABS pallets into acetone. After the ABS pallet dissolves, it takes on the appearance of a slurry and is then filled with filler metals TiO_2 (titanium) and W (tungsten) in the intended weighted(gram) proportion. Using a high-torque mechanical stirrer, the composite solution was stirred around 150 revolution per minutes, and compounded until it was ready to be combined. The viscosity at which metal filler particles could be mixed into the solution and remained suspended without sinking to the bottom. It has been swirled for three hours to completely blend the metal filler and ABS. Acetone begins to evaporate during the stirring process due to its volatility. These composite solutions made from compounded ABS and TiO_2W are now dried for 72 hours in a large surface area container. Here, any remaining solvent remnants are eliminated. Even after several drops of acetone in bubble form had blocked the sheet during the twin extruder extrusion operation, it was still impossible to remove it. The composite was subsequently extruded in a Twin extruder with the following temperature profile, as given in Table 1, in order to give the composite mixture additional uniformity. Various zone in the twin extruder is shown in Figure.2 [20].

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Table 1 Temperature profile along the extruder barrel

Feed zone	Compression zone	Metering zone	Die
180°C	200°C	210°C	230°C

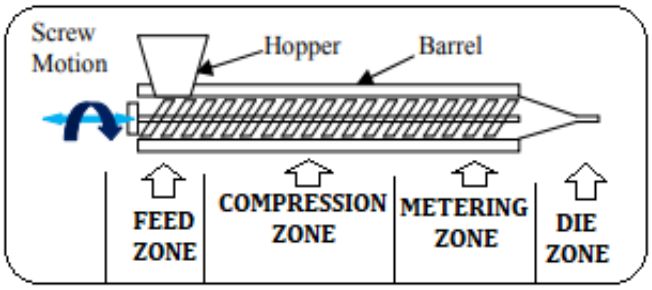


Figure 2 Temperature profiles of twin-screw extruder

Now that the pallet had been produced, it has dried completely for a further 80 hours.

2.3 Filament production

Once a pallet of appropriate required filler proportions has been developed, then filaments extruded, with the help of a single screw extruder, by using parameters mentioned in Table 1 For the first time in the literature, Panagiotis M. et al. studied the use of expanded perlite as filler for the extrusion-based fabrication of composite filaments made of ABS thermoplastic, and they also used composite filaments to print dog bone samples on a commercial 3D printer. Regarding the preparation of the filament, when fine filler ($d \geq 90$ μm) was employed, a significant portion of particles survived the extrusion process and were evenly distributed throughout the ABS matrix, but this was not the case for coarser ones, which appeared to crash during filament preparation[21]. The incorporation of Filler metal TiO_2 (Titanium) and W(Tungsten) into unfilled ABS, as designed is mentioned in *Table 2.* The Machine setup of LabTech manufacturers, India, has been used to develop Filaments of ABS Composites inside the Institute of Chemical Technology Campuses shown in Figure 3 and filament produced in Figure 4.

Table 2 ABS Composites fillers Compositions

Sr.no.	Sample Name	ABS %	TiO_2 (Titanium)	W(Tungsten)

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1	ABS	100	0	0
2	ABS/ TiO_2W/2.5	95	2.5	2.5
3	ABS/ TiO_2W/5	90	5	5
4	ABS/ TiO_2W/7.5	85	7.5	7.5
5	ABS/ TiO_2W/10	80	10	10



Figure 3 Single Screw extruder machine setup



Figure 4 ABS Composites Filaments ABS/TiO2W 5

2.4 Melt Flow Rate (MFR)

MFR parameters are used to describe the flow resistance(viscosity) properties of polymers. MFR

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is determined by measuring, the total amount of material (g) that is extruded, via a capillary, with standard dimensions in ten minutes, in accordance with ASTM-D-1238-95 standard [22,23]. ABS Polymer is the most widely applicable polymer for Additive manufacturing components in 3D printing technology, if any material has a flow rate superior to ABS, definitely applicable for 3D printing material for any complicated intricate shape and size with the assistance of slicing software. Hence for the purpose of analyzing its rheologic behavior, MFR was carried out with the temperature range 190 ^{0}C TO 220 ^{0}C.

2.5 Mechanical Characterizations

Prepared compositions of Unfilled ABS underwent Hardness and Impact testing. Hardness testing was performed using, a durometer seen in the Figure 6, to depict the Shore D hardness value of the specimen, as per ASTM D2240 standard. The instrument is manufactured and supplied by STI Ahmedabad, INDIA. Another property of unfilled as well as filled ABS, investigated is impact strength. Impact test of Izod test of fillers composition with Unfilled ABS compared as per ASTM 256D standard. An instrument used for carrying out impact test was as shown in Figure 5, from ICT Mumbai, General Engineering Departments Lab.

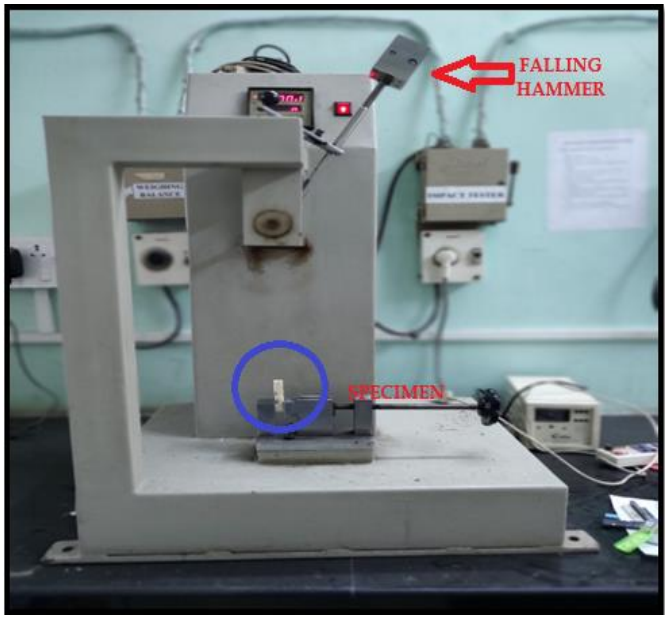


Figure 5 Impact test setup machine

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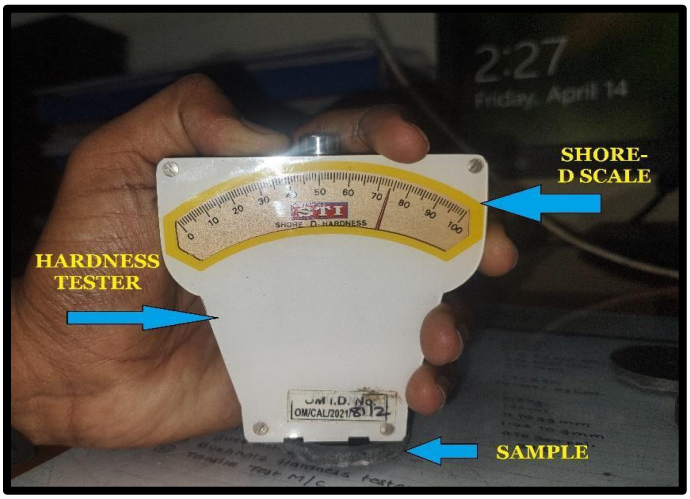


Figure 6 Shore D hardness tester (Durometer)

3. Results and discussion

3.1. Composite filaments morphology

As compounded composites have been fed to the single screw extruder and filaments have been produced. The temperatures of various zones are kept as used in the twin extruder mentioned in the Table 1. The below Figure shows filaments produced with the help of a single screw extruder having composites of 5 % weight(grams) fillers. Poor dispersion of additives, results in high viscosity, causes difficulty in processability of polymer composites. SEM imaging of cross-sections of filaments has been carried out which is shown in Figure 7, TiO_2W particles exhibit uniform dispersions. A few voids in the cross-sections were also observed.

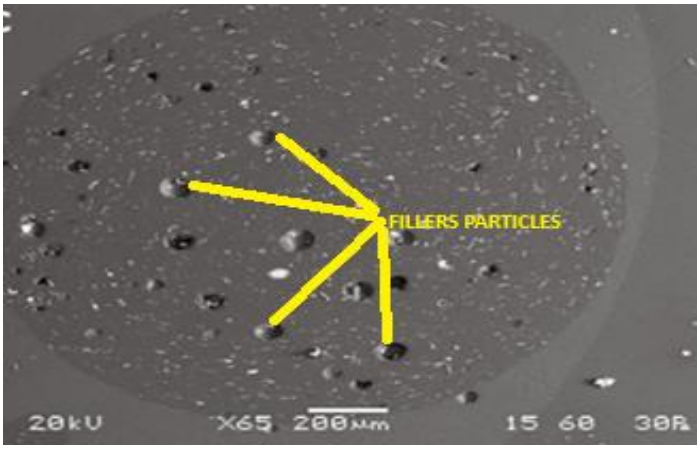


Figure 7 SEM image of filament cross section

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3.2 Melt Flow Rate [MFR] Analysis

Table 3 Melt Flow Rate Value of ABS composites

Sample of Composites	Melt Flow Rate (g/10 Minutes)	% Increase 0f Material Flow Rate
ABS	1.58	0
ABS/ TiO_2W/2.5	1.46	-8
ABS/ TiO_2W/5	2.81	78
ABS/ TiO_2W/7.5	2.95	87
ABS/ TiO_2W/10	3.1	96

A melt flow indexer was used, shown in Figure 8 as well as Table 3, to measure the composites' MFR. The die has a 2.01 mm diameter. This data has been collected at the Institute of Chemical Technology, Mumbai. Polymer Lab. The weight was limited to 5 kg, as per ASTM and the test temperatures were maintained at 200^0C. The MFR definition is provided by

$$\text{MFR} = \frac{\text{W}}{\text{t}} * 600 \quad (1)$$

where W is the extruded weight in grams within a time (t) of 10 min. Thus, the unit of MFR is grams/ (10 min) [24]. The Melt Flow Rate property analyzed by ASTM standard ASTM-D-1238 has been observed, that virgin ABS polymer poses an MFR value of around 1.58 g/10 minutes. An increase of MFR value with Additions of filler into unfilled ABS indicates a better Melt Flow Rate, and in converse, lowers the viscosity of composites by allowing more flow. This gives a new opportunity to the application of additive manufacturing composite material in 3-D printing. As ABS has, a 1.58 g/10 minutes value of MFR and ABS/ TiO_2W/2.5 observed having 1.85 g/10 minutes, slightly lesser than unfilled ABS. Which is almost near the value of pure ABS. With loading of TiO_2W by 5% weight(grams) gives a 78% higher MFR value compared to Unfilled ABS. Further incorporation of ABS/ TiO_2W/7.5 and ABS/ TiO_2W/10 saw, the subsequent increase of MFR value. It indicates that higher dual metal loading as a matrix reduces the viscosity of materials and allows easy flow through the die.

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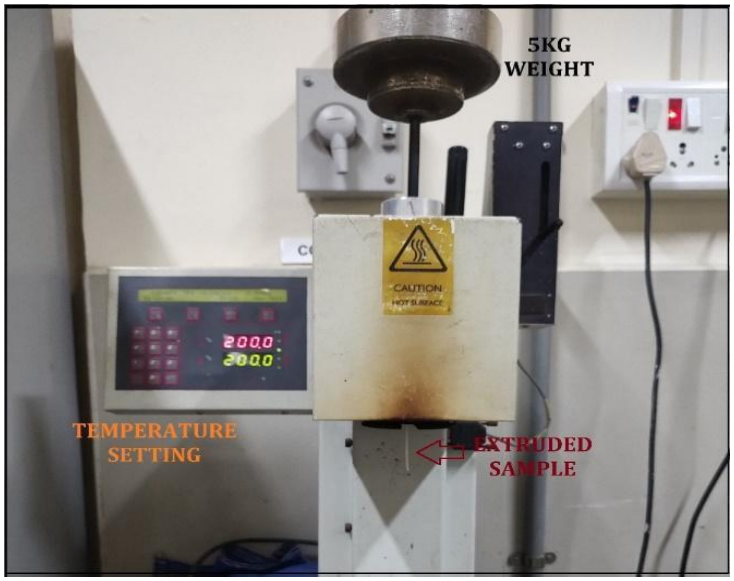


Figure 8 Melt Flow Rate testing equipment setup

3.4 Effect of filler TiO_2W (Titanium and Tungsten) on Mechanical Properties of Unfilled ABS polymer

3.4.1 Hardness Characterization

Polymer composites' hardness test provides a unique indication of their mechanical properties. The ABS/TiO_2W composites are described here using Shore D hardness techniques. Figure 10 displays the shore D hardness results. All test samples were compressed and molded into sheets, and specimens measuring 40 mm in diameter and 6.4 mm thick were removed from these sheets. To determine the relative hardness of each composition, an average of five readings have been collected. Unfilled ABS material has been determined to have a 70.2 shore D hardness. When compared to the hardness of the test sample without filler, the shore D hardness of all test samples with filler content of varied proportions increases. The shore D hardness increased to 73.2 with the addition of TiO2W by 2.5%, representing a 4.27% increase in hardness. Hardness was improved by 10.83% with the addition of 5% fillers and by 7.69% with the addition of 10% fillers. From this, we can infer that the maximum amount of filler that can be added to the composite to increase its shore D hardness is 7.5%. The loading of metal fillers in the composite is primarily responsible for the improvement in hardness. The shore D hardness of each sample composite is shown in Table 4, along with a percentage increase over unfilled ABS.

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Table 4 Shore D hardness value of ABS composites

Sample of Composites	Shore D Hardness	% Increase of Hardness
ABS	70.2 ±0.3	0
ABS/ TiO_2W/2.5	73.2 ±0.3	4.27
ABS/ TiO_2W/5	77.8 ±0.2	10.83
ABS/ TiO_2W/7.5	77.8 ±0.3	10.83
ABS/ TiO_2W/10	75.6 ±0.2	7.69

3.4.2 Impact Resistance characterization

As the impact resistance test taken by Izod test, which gives, absorbed energy of test specimen. As ASTM 256D five specimens, of each filler composition of ABS/TiO2W having V-notch at the mid of span. Below, samples of each filler loaded, and unfilled ABS seen**.**

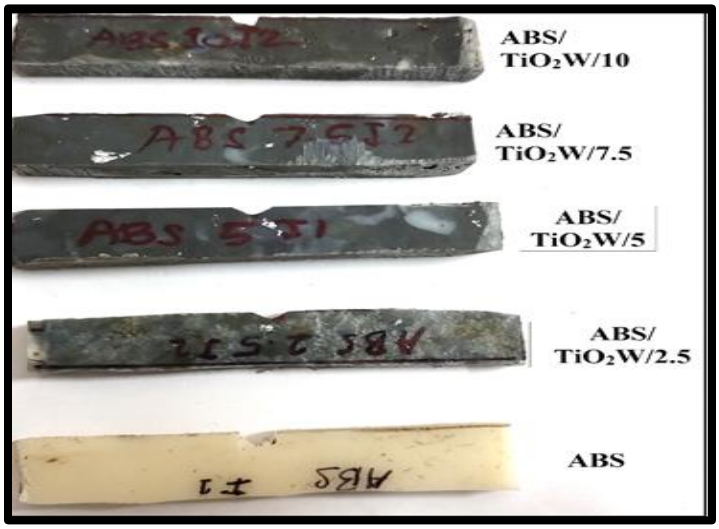


Figure 9 Izod test samples of ABS composites

Specimens of Impact test, having a dimension of (65x10x6.4) mm, with 2 mm notch, at its mid-span which is subjected by major load. Figure 9 shows the results of test specimens and by observing carefully the trend line of impact strength, of filler percentages that the addition of TiO2W reduced the impact strength. Composite samples of ABS/ TiO_2W/7.5, have the greatest impact strength, i.e. 11.34 kJ/m^2 , among developed composites. Similar impact strength trends have been depicted in, barite-filled ABS composites [25].

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Impact strength calculated mathematically by mentioned formulae[26],

$$Impact\ strength = \frac{\text{Average load break(Joul)}}{Width\ of\ specimen(metre)} \quad (2)$$

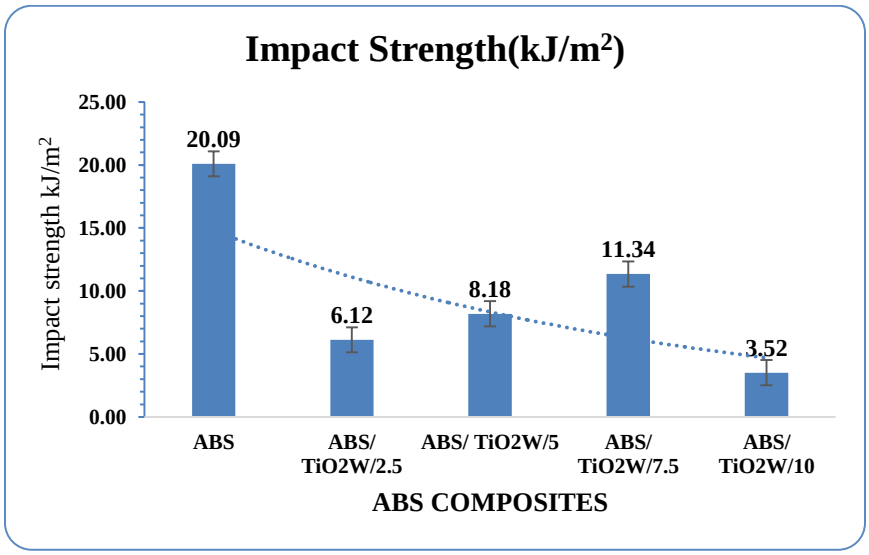


Figure 10 Impact strength of ABS composites with different Loadings

3.5 3D Printed Components Morphology

We have printed a 5% filler additive composite, of ABS/ TiO_2W/5, as during extrusion of filaments, the cross-section of sheets has been observed, and it shows, an increase in the amount of air gap, between layers. Figure 11 shows gaps, that are a result of the short filament diameter. The filament used for these prints, was within the 1.60 +/-0.5 mm specification, described in the methodology, it may have been on the lower end of the specification for longer lengths of filament, leading to a sparser deposit of infill, for the horizontally printed bars. Slicing was done in the pattern of 90/90.

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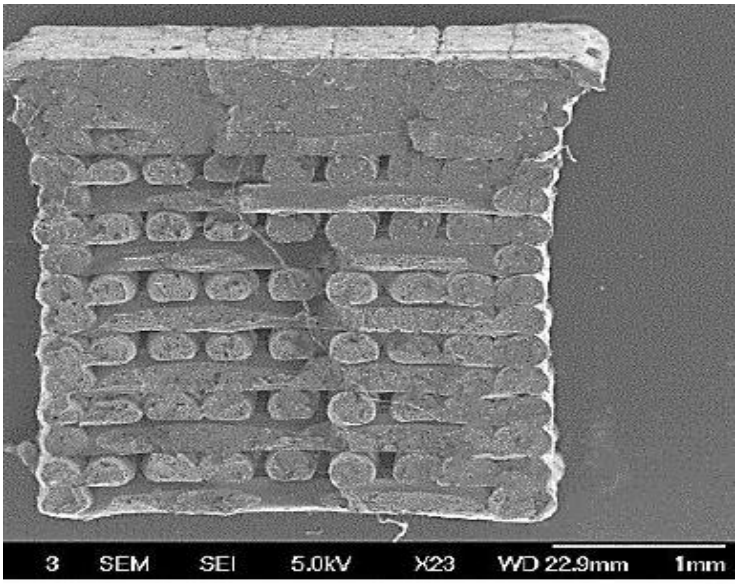


Figure 11 SEM image of 3D printed sheet cross section with voids

Conclusions.

1. ABS composites with dual metal fillers of Tungsten and Titanium, provide decent flowability which makes them helpful for 3D printing technology.

2. As the filler loading percentage goes higher, the Melt Flow Rate increases, which shows a lower viscosity of the molten condition of the filament, which may make it difficult to produce components at a faster rate because of solidification issues. Therefore, loading up to 5% filler of dual metal in composites is good enough for 3D printing.

3. Developing a few voids, as happens with fiber composites, is the Quality drawback, which is an area to be more focused on reducing and eliminating void formations.

4. Shore D hardness value shows that, as the loading of dual metal fillers as Titanium and Tungsten, increases, hardness also increases up to 7.5%, of weight(grams), but further again goes down. It gives the idea, that further incorporating fillers doesn't give any significant hardness improvement.

5. Impact strength of dual composites of polymers, gives similar behavior, as single fillers composite.

Declaration of Competing Interest

The authors affirm that they have no known financial or interpersonal conflicts that would have appeared to have an impact on the research presented in this study.

Acknowledgments

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GREEN ENERGY PRODUCTION THROUGH Fe_3O_4-rGO BASED HYDROELECTRIC CELL

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Abstract

Water splitting can be achieved using Hydroelectric Cells (HECs) made from oxygen-deficient, mesoporous metal oxides. Higher oxygen deficiency, surface area, and porosity in metal oxides enhance cell output by promoting water molecule dissociation. In this study, Fe_3O_4 was synthesized with reduced graphene oxide using a simple co-precipitation method, increasing surface area and porosity. The 4.08 cm^2 Fe_3O_4-rGO cell generated a short-circuit current of 16 mA and an open-circuit voltage of 1 V, significantly improving over pure Fe_3O_4. These results highlight its potential for broader applications in green energy.

Keywords

Hydroelectric Cell, metal oxide, water dissociation, Green Energy, Co-precipitation method

Introduction

In response to the global demand for renewable and eco-friendly energy sources, considerable attention has been directed toward the development of a novel hydroelectric cell (HEC) utilizing $Li_{0.2}Mg_{0.8}Fe_2O_4$ material [1,2]. The HEC presents a promising alternative for energy harvesting, being both environmentally friendly and sustainable. Functioning at room temperature, hydroelectric cells generate electricity by splitting water molecules on the nano-porous surface of oxygen-deficient metal oxide pellets. Initially, water chemisorbs to the pellet's surface, leading to the splitting into H^+ and OH^- ions. A continuous physisorption process ensues, with ions attracted by an electrostatic field generated by trapped H_3O^+ ions through the Groutthus mechanism. This further facilitates the dissociation of water molecules. The dissociated ions travel to the silver cathode and zinc anode, inducing an electric current through redox reactions. Simultaneously, the zinc anode transforms $Zn(OH)_2$, releasing highly pure hydrogen gas at the cathode [3-5].

This study outlines the fabrication process of Hydroelectric cells using Fe_3O_4 and Fe_3O_4-rGO nanoparticles. The choice of this material was driven by its exceptional qualities, including great adsorption capabilities, low toxicity, high mechanical strength, and remarkable biocompatibility, rendering it a distinctive and highly coveted substance. Magnetite's versatility has attracted considerable attention in diverse fields such as electrochemistry [6], catalysis [7], and spintronics [8]. The heightened interest is primarily due to its rare attribute of half-metallic conductivity, resulting from the coexistence of Fe^{2+} and Fe^{3+} ions.

Various studies explore Fe_3O_4-rGO nanocomposites' synthesis and applications. Yang et al. used solvothermal synthesis for enhanced NO_x gas sensing [9]. Nasripour et al. developed Li-

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ion battery anodes via solution composition [10]. Saha et al. investigated energy storage using a hydrothermal method [11]. Scaria et al. demonstrated Fenton catalyst efficacy for degrading antibiotics [12]. These applications showcase Fe_3O_4-rGO nanocomposites' versatility.

In this study, we employed the co-precipitation technique to synthesize Fe_3O_4 and Fe_3O_4-rGO nanocomposites, which were subsequently utilized in the fabrication of hydroelectric cells (HECs). These HECs underwent testing for power generation through water splitting. The off-load output powers for the Fe_3O_4 and Fe_3O_4-rGO HECs were measured at 3.95 mW and 17.76 mW, respectively. Significantly, the output power for the Fe_3O_4-rGO nanoparticles was notably higher than pristine Fe_3O_4 HEC. These findings highlight the potential of Fe_3O_4-rGO HEC as a viable and environmentally friendly alternative for power generation when compared to other green energy sources, as they do not contribute to the release of toxic waste into the environment.

Experimental Section

Materials

The raw materials employed included graphite fine powder (98%), potassium permanganate, anhydrous ferric sulfate (99%) , ferrous sulfate heptahydrate (99%) , hydrazine hydrate (80%), ammonia solution (25% NH_3), concentrated sulfuric acid (98% wt.), hydrogen peroxide, hydrochloric acid (98%) and deionized water. All chemicals used in the synthesis of Fe_3O_4 and Fe_3O_4-rGO were of analytical grade and were employed without any modifications.

Synthesis of pure Fe_3O_4 nanoparticles

The synthesis of Fe_3O_4 nanoparticles has been carried out using the co-precipitation method. To achieve this, 12g of $FeSO_4 \cdot 7H_2O$ and 17.27g of $Fe_2(SO_4)_3$ salts were dissolved in 200 ml of deionized water via magnetic stirrer for 2 hours at 80°C. Ammonia solution was gradually added until the observed pH was 10. The resulting precipitate was stirred for an additional hour, separated via centrifugation, and subjected to washing with acetone and deionized water until the pH reached neutrality. Following filtration, the obtained material was oven-dried at 60°C for 8 hours.

Synthesis of Fe_3O_4-rGO nanoparticles

The co-precipitation method was employed to decorate Fe_3O_4 nanoparticles on rGO sheets. Initially, 0.1g of GO powder, synthesized using the modified Hummer method, was sonicated in 100 ml of deionized water for two hours to create a colloidal suspension solution. Concurrently, 12g of $FeSO_4 \cdot 7H_2O$ and 17.27g of $Fe_2(SO_4)_3$ salts were dissolved in 200 ml of deionized water via magnetic stirrer for two hours at 80°C. Subsequently, the GO solution was added, stirred for an additional hour, and 0.5ml of hydrazine hydrate was introduced to reduce GO to rGO. After allowing the mixture to cool, the ammonia solution was gradually added until the observed pH was 10. The precipitate was further stirred for an extra hour, followed by centrifugation, separation, and washing with acetone and deionized water until the pH became neutral. Finally, the obtained material was oven-dried at 60°C for 8 hours.

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Fabrication process of Hydroelectric cell

Square pallets measuring 4.08 cm^2 were manufactured using a pallet press with a pressure of 6 tons, followed by sintering for 5 hours at 250°C. Subsequently, a 0.3 mm thick zinc sheet was affixed to one side, and silver was applied in a comb pattern on the opposite side. Additionally, soldering was employed to establish the necessary electrical connections. The image of fabricated Fe_3O_4-rGO based HEC is shown in Fig.1

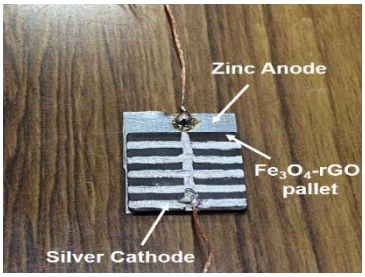


Fig.1. Fabricated Fe_3O_4-rGO based Hydroelectric cell

Characterization Techniques

The analysis of the phase, average crystallite size, and lattice strain for Fe_3O_4 and Fe_3O_4-rGO powder was conducted using a Shimadzu X-Ray Diffractometer with kα radiation of Cu, featuring a wavelength of 1.5406 Å, operating at 40kV/30mA, a scanning rate of 2.0°/min, and a sampling pitch of 0.02°. Porosity and specific surface area of the Fe_3O_4 and Fe_3O_4-rGO nanocomposite were determined through a nitrogen adsorption-desorption isotherm, employing the BET technique on a NOVA touch 4LX instrument by St 1. The voltage and current of the hydroelectric cells were measured using a Keithley-2430 1kW pulse source meter.

Results and discussion

X-ray Diffraction Analysis

The X-ray diffraction profile for the Fe_3O_4 and Fe_3O_4-rGO nanocomposite has been graphed in the 2θ range of 5-80°, as depicted in Fig. 2. The XRD pattern obtained for the Fe_3O_4 and Fe_3O_4-rGO nanocomposite affirms their formation by revealing unique peaks corresponding to Fe_3O_4 nanoparticles and rGO sheets around ~22°. This observation provides clear evidence of the coexistence of these components. Importantly, all distinctive peaks of Fe3O4 align with the standard pattern documented in JCPDS card no. 00-019-0629, confirming the inverse spinel crystal structure with the Fd-3m space group.

The Debye Scherrer equations were employed to calculate the crystallite size and lattice strain for the predominant peak of both Fe_3O_4 and Fe_3O_4-rGO composites, corresponding to the (311) plane.

For Crystallite size,

$$D = \frac{0.9\,\lambda}{\beta \cos\theta}$$

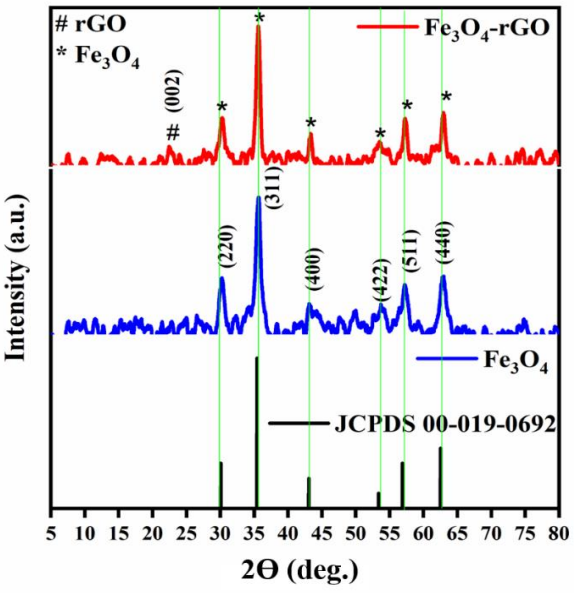


Fig.2. XRD pattern of JCPDS 00-019-0692 ,Fe_3O_4 and Fe_3O_4-rGO

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For lattice strain,

$$\varepsilon = \frac{\beta}{4\tan\theta}$$

In these equations, D represents the average crystallite size, ε denotes the strain, λ stands for the X-ray wavelength (1.5406), β represents the full width at half maximum, and θ signifies Bragg's angle in degrees. The obtained structural parameters for the Fe_3O_4 and Fe_3O_4-rGO nanocomposites are detailed in Table 1.

Table 1. Structural Parameters of Fe_3O_4 and Fe_3O_4-rGO via (311) Diffraction plane

Sample	Peak position (2θ) (degree)	FWHM (β) (degree)	Crystallite Size (nm)	Lattice Strain (ξ)
Fe_3O_4	35.54	0.65500	12.7	0.00892
Fe_3O_4-rGO	35.57	0.71000	11.7	0.00966

BET Analysis

The specific surface area, pore size as well as pore volume of both pure Fe_3O_4 and Fe_3O_4-rGO nanoparticles were evaluated using the BET Technique, as depicted in Fig. 3. Analysis of N_2 adsorption/desorption isotherms for both samples revealed a type IV behavior with H_2-type hysteresis loops. This behavior aligns with mesoporous characteristics according to the De Boer classification and IUPAC standards [13]. The observation of H_2-type hysteresis loops implies the presence of pores characterized by narrow mouths (resembling ink-bottle pores) and relatively uniform channel-like structures, as detailed in reference [14].

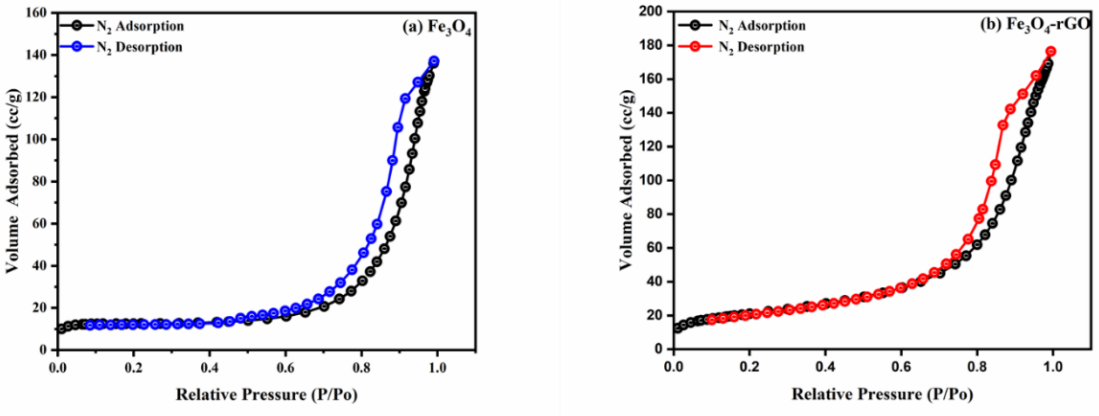


Fig. 3. (a,b) N_2 sorption isotherm, (c,d) the BJH plot and(e,f) surface area plot of Fe_3O_4 and Fe_3O_4-rGO nanocomposite

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(Fig. 3. Continue)

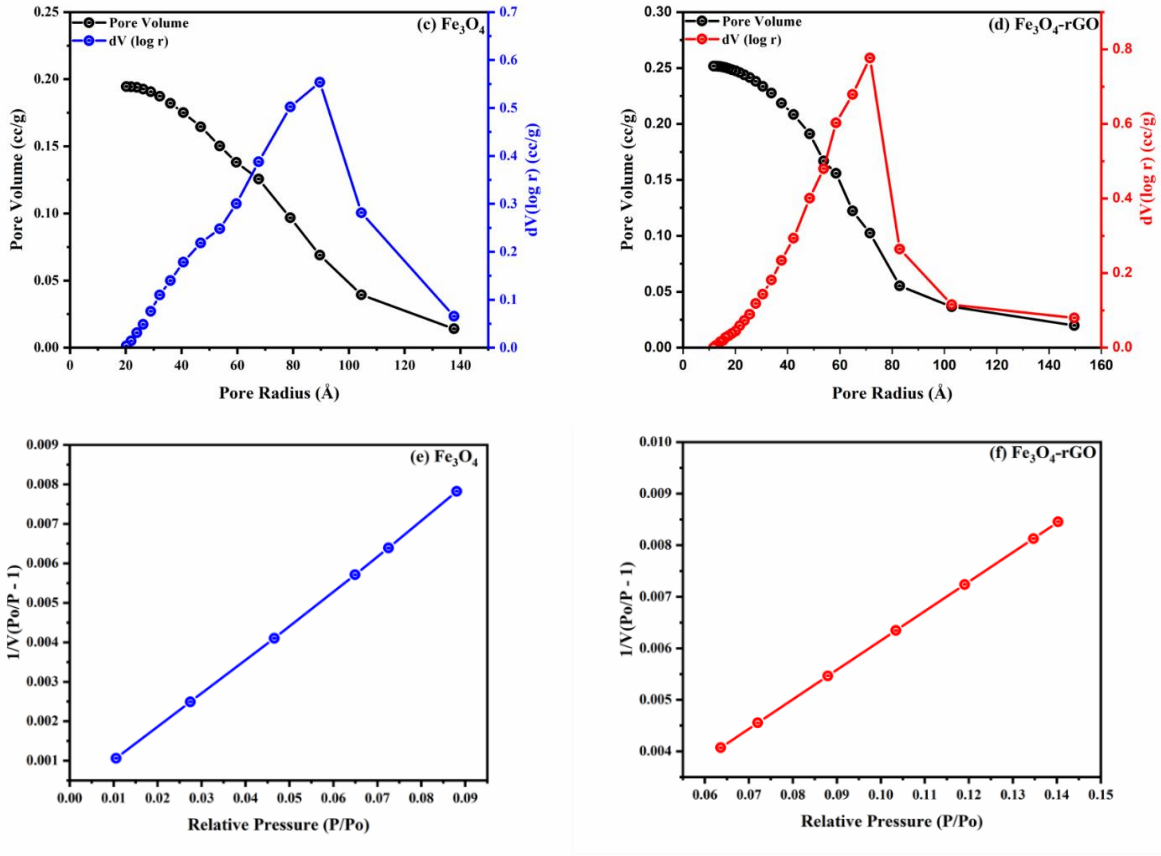


Fig. 3. (a,b) N_2 sorption isotherm, (c,d) the BJH plot and(e,f) surface area plot of Fe_3O_4 and Fe_3O_4-rGO nanocomposite

The specific surface area was assessed through the multipoint BET technique. Detailed information regarding pore size, pore volume and surface area for both pure Fe_3O_4 and Fe_3O_4-rGO nanocomposites is provided in Table 2.

Table 2. Data on Surface Area, Pore Radius, and Pore Volume for Fe_3O_4 and Fe_3O_4-rGO Nanoparticles

Sample	Sample area (m^2/g)	Pore radius (Å)	Pore Volume (cc/g)
Fe_3O_4	50.0283	6.07	0.21218
Fe_3O_4-rGO	75.6491	5.32	0.27284

V-I Polarization Plots

The operation of Fe_3O_4 and Fe_3O_4-rGO HECs is depicted through the V-I polarization curve, illustrating the relationship between cell voltage and operating current, as presented in Fig. 4.

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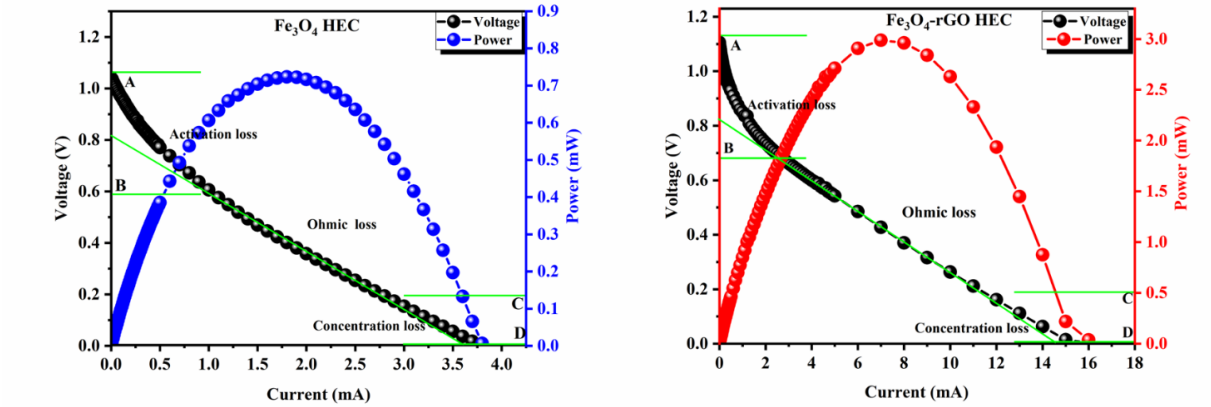


Fig. 4. V-I Polarization curves and power generated by Fe_3O_4 and Fe_3O_4-rGO nanocomposite.

When distilled water was dropped on the surface of fabricated HEC, it generated a short circuit current, an open-circuit voltage, and, subsequently, the off-load power, as detailed in Table 3.

Table 3. Output parameters of fabricated HECs

Hydroelectric cell (HEC)	Open circuit voltage (V)	Short circuit current (mA)	Off-load Power(mW)
Fe_3O_4 HEC	1.04	3.8	3.95
Fe_3O_4-rGO HEC	1.11	16	17.76

Conclusions

We prepared Fe_3O_4 and Fe_3O_4-rGO nanocomposites using co-precipitation. Adding rGO to Fe_3O_4 changed the crystallite size from 12.7nm to 11.7 nm and the lattice strain from 0.00892 to 0.00966. as indicated by the XRD analysis. This addition also increased the surface area (50.03 m^2/g to 75.65 m^2/g) and pore volume (0.21218cc/g to 0.27284 cc/g) as indicated by the BET analysis. The Fe_3O_4-rGO HEC (4.08 cm^2) produced an off-load power output of 17.76 mW, outperforming the Fe_3O_4 HEC (3.95 mW) which is indicated by the VI polarization plots. This water-splitting method is efficient and eco-friendly, showcasing the potential of Fe_3O_4-rGO HEC as a cost-effective green energy source.

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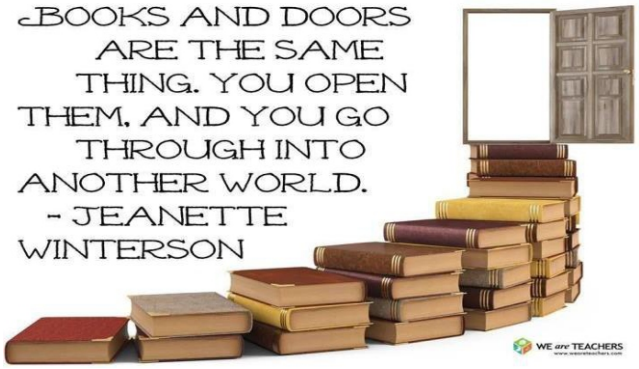
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