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International Conference on Science, Engineering & Technological Innovations - 2024

International Conference on Science, Engineering & Technological Innovations

Date: 18 – 19 October, 2024

E-Book / Conference Papers

Editors

Dr. Jessica C.
Dr.(hc) Rania Lampou
Dr. C. M. Patel

Jointly organized by :
International Scientific Research Association
Department of CSE, Carmel College of Engineering and Technology
(affiliated to APJ Abdul Kalam Technological University, Kerala, India)
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The Department of Computer Science and Engineering (CSE) at Carmel College of Engineering and Technology, Alappuzha, was established in 2017 with an initial intake of 60 students. In recognition of its growth and excellence, the intake was enhanced to 120 students per year in 2024. Since its inception, the department has been dedicated to providing quality education, fostering innovation and equipping students with the technical skills and professional values required to excel in today's technology-driven world. The department plays a vital role in enhancing learning and technical competence, offering students a strong foundation in core computer science subjects while encouraging them to explore cutting-edge technologies.

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'International Scientific Research Association' (Scientific Research Organization) is an esteemed research organization working on to promote scientific research studies, activities at international level, also coordinate with other research organizations for the educational research events.

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- To meet and discuss the practical solutions, scientific results and methods in solving various problems with people who are actively involved in emerging research fields.
- To organize lectures by scientists and experts and to disseminate their ideas and concepts among the science and technology community.
- Provide the delegates to share their new ideas and the application experiences face to face.
- The aim of the conference is to provide platform to students, scholars, academicians and industry persons to converse and share the ideas.

About the Conference :

International Conference on Science, Engineering & Technological Innovations (ICSETI-2024) conducted on 18 – 19 October, 2024. It aims at bringing together students, scholars, researchers, academicians and industry persons to deliberate on contemporary issues concern to Science, Engineering and Technology research and applications.

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Science, Engineering and Technology cross nearly every facet of modern life and, as problem solvers, engineers are perfectly capable of managing technical activities, mastering innovative ways of science and engineering field, when they spend time and efforts understanding and acting in the field. Scientific and technological innovation, as strategic support to improve social productivity and overall national strength, must be placed at the center for development of any country.

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The special issue / conference proceedings / edited book is a collection of peer-reviewed scientific papers submitted by active researchers in the International Conference on Science, Engineering & Technological Innovation. This book can be helpful to understand the various concepts of Science and Technological Innovation to the researchers and academia.

Dr.Jessica Chocha
Bahauddin Science College, BKNMU.
Editor / Editorial Member, ICSETI-2024

Editor Contribution & Message

It is with great pleasure that I present this editorial for the Science and Technology Conference, a platform that brings together researchers, innovators, and practitioners to exchange ideas that shape the future of our world. Science and technology continue to be the driving forces behind societal progress, addressing complex global challenges while opening new frontiers of knowledge and application.

This conference serves as a vital forum for interdisciplinary dialogue, encouraging collaboration across domains such as artificial intelligence, sustainable technologies, advanced materials, biotechnology, and data-driven systems. The contributions featured here reflect both theoretical information and practical solutions, emphasizing innovation with real-world impact. Such convergence of ideas is essential in translating research into technologies that benefit humanity. The editors have contributed to check each abstract and full papers for the ISBN publication edition.

I extend my sincere appreciation to the authors, reviewers, organizing committee, and participants whose dedication and expertise have ensured the high quality of this conference. Their collective efforts demonstrate a strong commitment to scientific rigor, ethical responsibility, and technological excellence.

It is my hope that the discussions and findings presented will inspire new research directions, foster meaningful collaborations, and contribute to the advancement of science and technology. I wish all participants a productive and intellectually enriching conference experience.

Dr.Jessica Chocha
Bahauddin Science College, BKNMU.

Anoop. R.S. Department of CSE,
Carmel College of Engineering and Technology
ICSETI - 2024 Conference Coordinator

Message of Conference Coordinator

Dear Colleagues !

I am grateful to co-organizing institutions, all the speakers, committee members and presenters of 'International Conference on Science, Engineering & Technological Innovations' (ICSETI-2024) The overwhelming response to the contributors were acknowledged in very positive manner and its shows that new age is very much eager to work with technical literature. The rising researcher and scholar from various institutions and in-house participants motivate us to improve ourselves.

We are currently in the era of science and engineering revolution, spearheaded by recent developments in engineering, technology and sciences, providing sustainable solutions to various issues.

Here I am delighted that the series of conference on contemporary issues in computer technology has successfully completed its three folds and entered into fourth one, it's all due to the valuable efforts of faculty members of computer science and engineering department.

I extend my best wishes for the editorial team of the special issue, at last I hope this technological literature interaction will be a source of inspiration to upcoming educationists, technocrats and stakeholders.

Anoop. R.S. Department of CSE,
Carmel College of Engineering and Technology
ICSETI - 2024 Conference Coordinator

Dr(hc) Rania Lampou
President, Eurasian Research Organization
Email : info@eurasianresearch.org

MESSAGE

Dear Colleagues !

I am glad to be the part of Organizational Committee of "International Conference on Science, Engineering & Technological Innovations' (ICSETI-2024)", jointly organized by 'International Scientific Research Association' and Eurasian Research Organization, in collaboration with 'Research Culture Society' (18 – 19 October, 2024).

We have an exciting program at the conference that will allow participants a good platform to present their research work, extend networks, and future research directions. I hope that all participants will have a productive approach at this online conference.

I sincerely hope that this conference will deliberate and discuss all the different facets of this exciting topic and come up with recommendations that will lead to a better world.

I wish the conference great success.

Dr(hc) Rania Lampou
President, Eurasian Research Organization,

Dr.C. M. Patel

Director, RESEARCH CULTURE SOCIETY

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Message

Dear Professional Colleagues,

It is gratifying to note that 'International Scientific Research Association'; Eurasian Research Organization and ISRA in collaboration with 'Research Culture Society' (Government Registered Scientific Research organization) are organizing - 'Eurasian Conference on Science, Engineering & Technological Innovations' during 18 – 19 October, 2024.

The aim of the conference is to provide an interaction stage to researchers, practitioners from academia and industries. The main objective is to promote scientific and educational activities towards the advancement of common citizen's life by improving the theory and practice of various disciplines of science and engineering. Provide the delegates to share their new research ideas and the application experiences face to face.

I believe, this International Conference will help in redefining the strong connection between students and academicians from different institutions. An additional goal of this international conference is to combine interests and scientific research related to General Science, Physical Science, Applied Sciences, Engineering and Technology Development to interact with members within and outside their own disciplines and to bring people closer for the benefit of the scientific community worldwide.

My best wishes to the committee members, speakers and participants of this scientific conference ICSETI-2024.

Dr.C. M. Patel
Director, Research Culture Society.

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TABLE OF CONTENTS

ISBN: 978-81-976827-5-9

Static Refraction Test (A Geophysical Tool) For Thane Creek Portion (Underwater) For 21km Long Undersea Tunnel, Mumbai Ahmedabad High Speed Rail Project, Mumbai

Dr. Yogesh Kumar
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Email - yogeshkumar@rites.com

Abstract: *The static refraction test (SRT) was carried out for 21 km long undersea tunnel of MAHSR project for the first time in India to decipher the subsurface characteristics of the rockmass under water for design.*

This work summarizes the results and interpretations of SRT survey along the proposed alignment with aim to obtain the quantitative overburden material and firmed rock depth and weathered and hard rock interface with its thickness to identify anomalous zones within the rock mass its condition of the proposed tunnel under water.

SRT was carried out on 2 longitudinal lines along the center line of alignment (1.6km), and 8 cross lines of 590m length at 200-300m spacing.

Based on seismic velocity (Vp) of different layers, engineering properties of rock mass ***"Q" & "RMR"*** *have been assessed by using empirical relations of Barton and rock mass strength* ***"σc"*** *through Linear Regression Equation by* ***Freyburg, 1972.***

In addition to Barton's relationship, Japanese classification standard for Mountain tunnel, 2008 has also been adopted to access the rock mass grade. ***Q & RMR****,* ***rock mass grade*** *and* ***"σc"*** *are vital inputs, which are used for design of tunnel based on SRT.*

SRT results along the alignment shows top most layer (1.17m to 55.20m with Vp of 1600-2200m/s) sea sediments along with highly to completely weathered rock having followed by bedrock (2m to 40m with Vp of 2800-5100m/s). Lower Vp of 2800-3500m/s indicates strongly weathered and jointed nature of basalt with Q value varies from 0.2 to 1.0 and RMR of 40 to 50, categorized as ***very poor*** *with* ***rock mass grade "I_N"****.*

*At tunnel grade, Vp of 3300-4200m/s interpreted as slightly weathered to fresh less jointed basalt, moderately strong to strong with Q value varies from 0.63 to 5.01 and RMR 47 to 51 categorized as very poor to fair. Rock mass strength (****σc****) varies from 84MPa to 115.5MPa categorized as* ***very poor to fair*** *with* ***rock mass grade "II_N to III_N"****.*

*Vp of the order of 4600-5100m/s interpreted as fresh basalt, strong with Q value of 12.59 to 39.81 and RMR 67 to 74. Rock mass strength (****σc****) varies from 129.5MPa to 147MPa categorized as* ***good*** *with* ***rock mass grade "IV_N"****.*

Key Words: *Tunnel, SRT, MAHSR, Q, RMR, rock mass, strength, grade.*

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1. INTRODUCTION:

India's first High Speed Rail project is proposed from Mumbai to Ahmedabad (510km) is planned by Railway Board and Railway Board has entrusted RITES for conducting FLS & Geotechnical investigation work. Most important and problematic is conducting investigation of undersea tunnel passing through Thane creek area under water (Figure-1.1).

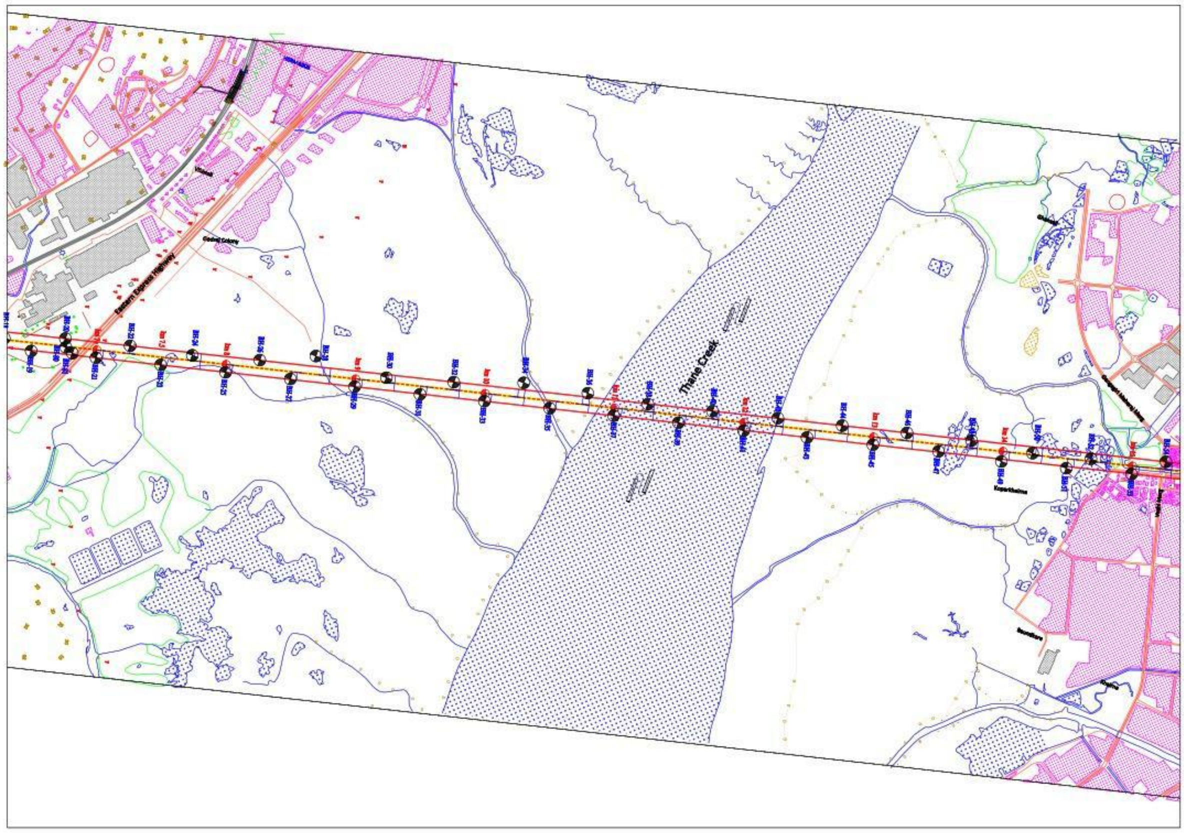

Figure-1.1 - Location map of the 21km long undersea tunnel showing Thane creek area (Blue colour) in Mumbai

In the present study, total ten seismic spreads were acquired at selected location in Tunnel -1 with a total length of 6281m, and the range of 1602 m was covered along the alignment within them (Figure-1.2). The data acquisition was carried out in December 2017. Bathymetric survey has been carried out along seismic lines. The position of the source was controlled by DGPS. The position of all receivers was determined by the same principle as the hypocenter determination using the arrival time of the direct water wave generated from the source.

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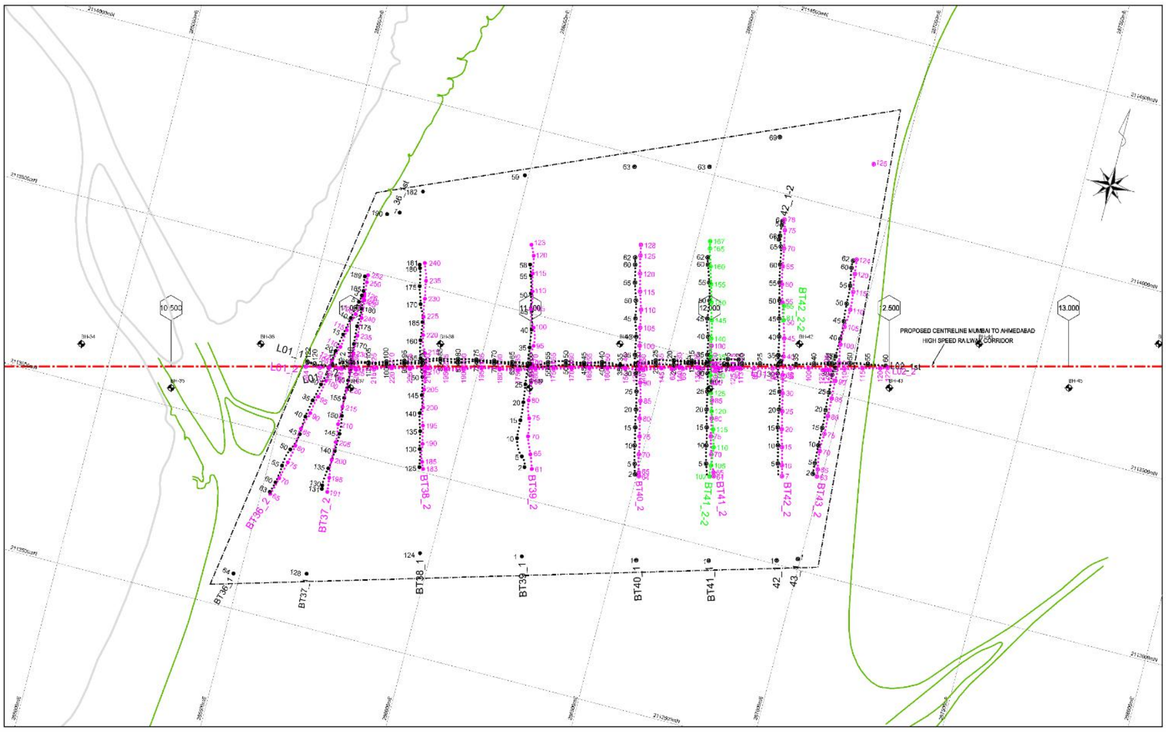

Figure-1.2 Seismic line spread plan

2. OBJECTIVES :

Surface geophysical investigations have been conducted to ascertain the depth of overburden comprise of slope debris under saturated and un- saturated condition along with rock slumps, weathered rock layer and depth of bedrock along with its condition. The objective of the survey is to assess velocity and associated thickness of different geological "layers" observed at the site e.g.

- Mapping of subsurface stratigraphy
- To map the subsurface layer with variation of seismic velocity with thickness,
- To delineation of overburden, weathered, fracture/jointed and fresh bedrock mass along the profile.
- To determine low velocity zones within the fresh bedrock if any.

  The interpretation of the geophysical data has been correlated with Geological Mapping and the results of confirmatory drilling data.

3. METHODOLOGY :

SRT is one of the important tools based on seismic waves travel with different velocities in different rocks. By generating seismic waves at a point and observing the time of arrival of these waves at a number of other points on the surface of the earth, it is possible to determine the velocity distribution and locate the subsurface interfaces where the waves are reflected or refracted.

In recent marine seismic survey, as a group of receivers, a number of independent ocean bottom seismographs are arrayed in a line (Figure-3.1), or in a shallow sea, a receiver cable to which a number of sensors are connected like a bay cable is used. An air gun is also commonly used as source energy.

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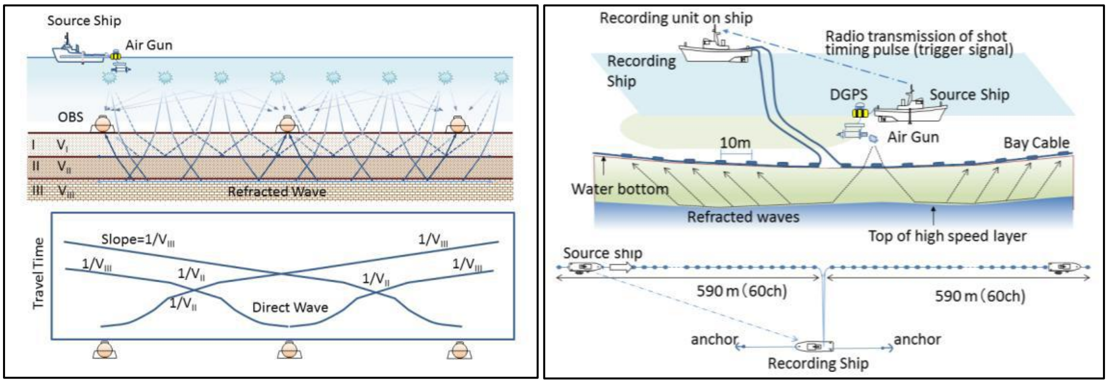

Figure-3.1 & 3.2: Diagram showing theory and field setup of marine seismic refraction test

Seismic (P-Wave) velocity of materials relates to the strength properties and the degree of weathering and joints available in-situ. This defines rocks in various sub-categories such as Hard, Weathered and Soft in terms of range of P-wave velocities. Therefore, a comprehensive knowledge of the seismic velocities in different medium is the basis of the interpretation of seismic survey data.

The seismic survey was conducted in WGS84 datum, Universal Transverse Mercator (UTM) Projection and was controlled by DGPS. SRT has been carried out at Tunnel site to determine overburden, bed rock configuration & its characteristic with thickness & compression (P) wave velocity for soil and bed rock in alignment.

In this survey, a marine refraction exploration technique was used. The nitrogen air gun was used as a seismic source and the bay cable consisting of numerous hydrophones as receivers used, which was a marine seismic cable that was installed on the water bottom. Two units of bay cable with 590m in length with one unit incorporating 60 hydrophones at 10m interval were deployed. Schematic diagram of Marine Seismic Survey is shown in Figure-3.2.

In the specification, the receiver interval was 5m. However, since hydrophone interval was 10m, by setting the shot interval to 5m, we made an equivalent investigation with a receiver interval of 5m. Nitrogen cylinders were used as energy source of the air-gun and the trigger signal was transmitted by a radio from the source ship to the recording ship (Figure-3.3).

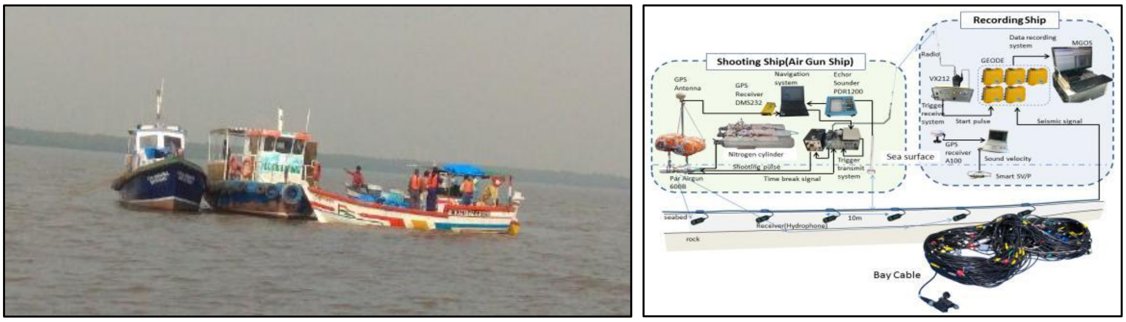

Figure-3.3: Site photo and schematic diagram in the field.

The position of the source was controlled by DGPS. The position of all receivers was determined by the same principle as the hypocenter determination using the arrival time of the direct water wave generated from the source. In this calculation, the depth of the receiver was fixed to the depth of the water bottom which was subjected to tidal correction.

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The Bathymetric survey was carried out during refraction survey by the shooting boat using onboard echo sounder PDR1200. The echo sounder measured sea depth with very high frequency. The water depth by PDR1200 system were recorded every air gunshot (about every 5m), and at the same time GPS data was also recorded by the navigation PC. From the sounding data obtained in this manner, bathymetric sections along SRT lines were created after correcting the tide level.

The bathymetric data was used for static correction of the shot depth, and to determine the position of all hydrophone sensors.

4. DATA PROCESSING & INTERPRETATION

Analysis of the seismic data acquired in the field was checked on the apparent velocity of bedrock on the monitor display of the seismograph. However, final processing and analysis of SEG-Y data has been done through “PASTEUP” and “MODELING” software developed by KGE (Figure-4.1 & 4.2).

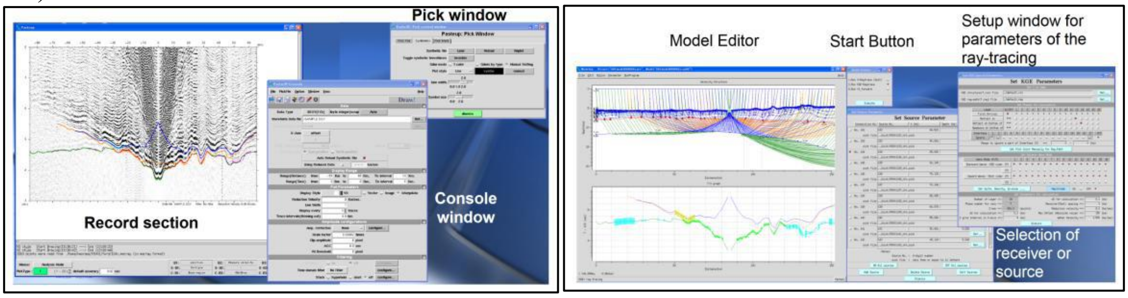

Figure 4.1 & 4.2: A screen image of Record section using “PASTEUP” and “MODELING” software

Based on the observed velocities in the surveyed area, following four subsurface stratification has been made as shown in Table- 4.1.

Table 4.1: Classification of Subsurface Strata in terms of Seismic wave velocity

Layer No.	Seismic velocity (m/s)	Inferred Lithology
1	1600 –2200	Sea sediment with highly to completely weathered basalt
2	2800 –3500	Strongly weathered and jointed/Fractured basalt
3	3300 – 4200	Slightly weathered to fresh less jointed basalt
4	4600 - 5100	Fresh basalt

Seismic Velocity of sea water has been measured during the survey in each seismic line. Average seismic velocity of sea water is 1530 m/s. Seismic sections brought out the detail insight information about the subsurface stratigraphy in terms of their seismic velocities, which are directly related to the quality and the strength of the medium.

5. ENGINEERING PROPERTIES OF ROCK MASS

Seismic velocities in the rock mass can be correlated to other engineering properties by specific empirical relationship. By using these empirical relations, Q- value of the strata encountered can be assessed. This is based on an empirical relationship (Barton et al, 1993) used extensively in civil engineering practice as shown in Table-5.1 & 6.1. This parameter is a vital input for design consideration for any subsurface excavation and is widely used as a correlation tool with SRT.

Table 5.1: Empirical relationship between Seismic Wave Velocity Vp and Q-Value and Barton’s Rock mass classification

Vp in m/sec	1500	2500	3500	4500	5500	6500
Q-Value	0.01	0.1	1.0	10.0	100.0	1000.0

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Rock mass category	Exceptionally Poor	Extremely poor	Very poor	Good	Very good	Exceptionally good

Reference:-Strategy for a Rock Mechanics Site Descriptive Model Development and testing of the empirical approach Chapter-2, Page No.24 - By Kennert Röshoff and Flavio Lanaro, Berg Bygg Konsult AB and Lanru Jing, Division of Engineering Geology, Royal Institute of Technology, March 2002.

Based on the seismic velocity, rock mass classification as per Barton's 'Q' values has been attempted for stability of excavation of tunnel. The empirical relations used for calculation of the parameters are referred as under:

1) Rock Quality $Q = 10^{\left(\frac{Vp-3500}{1000}\right)}$ **(Bieniawski, Z.T., 1993)**
2) *RMR* = 15 log Q + 50 **(Barton's et al. 1995**)
3) Rock mass strength σ_c= (0.035*Vp -31.5) Linear Regression Equation by **Freyburg, 1972**

6. JAPANESE ROCK CLASSIFICATION

Based on huge experience of tunneling in different rock environment by Japan and after analyzing those data obtained from tunneling, suitable relation between rock mass and tunneling support system has been developed **"The Standard of design & Construction of Mountain Tunnel"** in 2008 by JRTT (Japan Railway Construction, Transport and Technology Agency). Based on the rock type, elastic wave velocity (Vp: km/s), rock mass grade and support pattern standards have been established as per the Tables-6.1 to 6.3.

Japanese classification on rock mass grade is based on the geological formation and the anticipated elastic wave velocity (Vp) within that rock mass.

The tunnel could be constructed in the rock mass grade interpreted at layer-3 and layer-4. The velocity of layer-3 and layer-4 are "3.3 – 4.2km/s" and "4.6 – 5.1km/s". The geology at Thane creek completely covered under Volcanic Rock (Basalt), so the rock type in Table-6.2 is ④ of "A". Taking into consideration of these two factors, the rock mass grade are in IIN, IIIN and IVN in Table-6.1. Finally, "Standard Support Pattern" is obtained as shown in Table-6.3, which means not heavy support.

Table 6.1: Japanese classification standard of Rock Mass

Rock Mass Grade	**Hard Rock**			**Medium Rock**	**Soft Rock**	**Soil**	
	Rock Type A	**Rock Type B**	**Rock Type C**	**Rock Type D**	**Rock Type E**	**Rock Type F・G**	
						Cohesive Soil	**Sandy Soil**
V_N	Vp≧5.2		Vp≧5.0	Vp≧4.2			
IV_N	5.2＞ Vp≧4.6		5.0＞ Vp≧4.4	4.2＞ Vp≧3.4			
III_N	4.6＞ Vp≧3.8	Vp≧4.4	4.4＞ Vp≧3.6	3.4＞ Vp≧2.6 And Gn≧5	2.6＞ Vp≧1.5 And Gn≧6		
II_N	3.8＞ Vp≧3.2	4.4＞ Vp≧3.8	3.6＞ Vp≧3.0	2.6＞ Vp≧2.0 and 5>Gn≧4	2.6＞ Vp≧1.5 and 6＞Gn≧4		
I_N	3.2＞ Vp≧2.5	3.8＞ Vp≧2.9	3.0＞ Vp≧2.5	2.6＞ Vp≧2.0 and 4＞Gn≧2 or	2.6＞ Vp≧1.5 and 4＞Gn≧2	Gn≧2	Dr≧80 and Fc≧10

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				2.0＞Vp≧1.5 and Gn≧2.0			
I_S	2.5＞Vp	2.9＞Vp	2.5＞Vp	1.5＞Vp or 2＞Gn≧1.5	1.5＞Vp or 2＞Gn≧1.5	2＞Gn≧1.5	
I_L							Dr ≧80 and 10＞Fc
S_S				1.5＞Gn	1.5＞Gn	1.5＞Gn	
S_L							80＞Dr

Table 6.2: Japanese Rock Classification

Rock Type	Geological Age・Rock Name
A	① Paleozoic, Mesozoic Sedimentary Rock (Slate, Sandstone, Conglomerate, Chert, Limestone, etc.) ② Plutonic Rock (Granite,etc.) ③ Hypabyssal Rock (Porphyrite, Granite Porphyry, etc.) ④ Volcanic Rock (Hard Basalt, Andesite, Ryorite. etc.) ⑤ Metamorphic Rock (Schist, Gneiss, Phyllite, Hornfers, etc.)
B	① Highly Cleavable Metamorphic Rock (Schist, Pyillite, Gneiss) ② Highly Cleavable or Fine Bedding Paleozoic and Mesozoic Sedimentary Rock (Slate, Shale, etc.)
C	① Mesozoic Sedimentary Rock (Shale, Slate) ② Volcanic Rock (Rhyolite, Andesite, Basalt, etc.) ③ Paleogene Sedimentary Rock (Shale, Mudstone, Sandstone, etc.)
D	① Neogene Sedimentary Rock (Shale, Mudstone, Sandstone, Conglomerate, Tuff, etc.) ② Paleogene Sedimentary Rock ③ Weathered Igneous Rock
E	① Neogene Sedimentary Rock (Mudstone, Siltstone, Sandstone, Conglomerate, Tuff, etc.) ② Weathered, Hydrothermal-altered, Fractured Rock (Igneous Rock, Metamorphic Rock and Pre-Neogene Sedimentary Rock)
F	① Diluvium Sediment (Low consolidated or Unconsolidated Sediment composed of Gravel, Sand, Silt, Mud and Volcanic Ash) ② Neogene Sediment (Low Consolidated or Unconsolidated Soil, Hardpan, Sand, etc.) ③ Weathered Granite
G	Top Soil, Debris, etc.

Table 6.3: Japanese Standard Support pattern for Tunnels

Standard Support Pattern	Rock Bolt			Thickness of Shotcrete (cm)		Steel Support
	Arrangement	Length (m) ×Number (No)	Spacing (m)	Arch, side wall	Invert	Type
IVN				5 (average)		
IIIN	Arch	2×0~5	optional	10 (average)		
IIN	Arch	3×10	1.5	10 (average)		

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IN	Arch, side wall	3×14	1.0	15 (minimum)		125H
IS	Arch, side wall	3×14	1.0	15 (minimum)	15 (minimum)	150H
IL	Arch, side wall	3×12	1.0	20 (minimum)		125H

7. DISCUSSION :

The rock mass is classified as per both Q-system (Barton et al., 1974) and RMR System (Barton et al., 1995/9) and the Japanese rock mass classification standard for Mountain tunnel, 2008. Japanese rock classification and the standard of support system have been developed based on the elastic wave velocity (Vp in km/sec). On the basis of seismic velocity (Vp) and "Q" value of different layers, an overall appraisal of the rock mass classification, strength (σ_c), RMR, have been assessed & placed at Table-7.1.

Table 7.1: Interpretation of Seismic Sections from Ch. 10.882 - 12.484km (Thane Creek)

Chainage (m)	**Layer No:**	**Velocity Vp (m/s)**	**Thickness (m)**		**Q**	**RMR**	**Intact Rock Mass strength (σc in Mpa)**	**Interpreted Lithology**	**Rock Mass Classification Based on Q**	**Japanese Rock Mass Classification**	
			From	**To**							
10882 - 12072	1	1600 - 2200	1.178	55.19	0.01 - 0.05	22 - 31	24.50 - 45.50	Sea sediment with highly to completely weathered basalt	Extremely poor	-	-
	2	2800 - 3500	5	30.642	0.20 - 1.00	40 - 50	66.50 - 91.00	Strongly weathered and jointed/ Fractured basalt	Very poor	II_N	A
	3	4000 - 4200	5.27	33.58	3.16 - 5.01	58 - 61	108.50 - 115.50	Slightly weathered to fresh Less jointed basalt	Fair	III_N	A
	4	4600 - 5000	-	-	12.59 - 31.62	67 - 73	129.50 - 143.50	Fresh basalt	Good	IV_N	A
11894 - 12484	1	1600 - 2200	1.176	6.04	0.01 - 0.05	22 - 31	24.50 - 45.50	Sea sediment with highly to completely weathered basalt	Extremely poor	-	-
	2	2800 - 3500	0.94	17.046	0.20 - 1.00	40 - 50	66.50 - 91.00	Strongly weathered and jointed/ Fractured basalt	Very poor	II_N	A
	3	3300 - 4200	5.582	27.31	0.63 - 5.01	47 - 61	84.00 - 115.50	Slightly weathered to fresh Less jointed basalt	Fair	II_N	A
	4	4800 - 5100	-	-	19.95 - 39.81	70 - 74	136.50 - 147.00	Fresh basalt	Good	IV_N	A

Interpretation of seismic data is based on the standard ranges of velocity of earth's material and correlation with local geological information and litho-stratification obtained through geological logs.

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Geologically, four different types of volcanic rock have been identified with varying degree of weathering in the area as (i) sea sediment with highly to completely weathered basalt, (ii) strongly weathered basalt, (iii) slightly weathered basalt and (iv) fresh basalt. Although the first layer consists of unconsolidated sea sediments and highly to completely weathered basalt, it cannot distinguish its velocity boundary from the results of this SRT.

Based on the interpretation it is concluded that the interpreted seismic sections are well matched with the geological logs as shown in Figure-7.1 & 7.2.

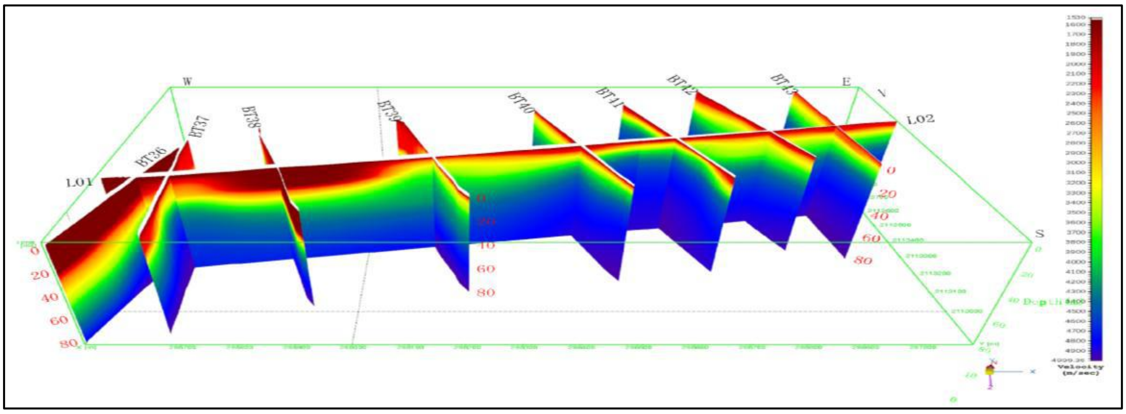
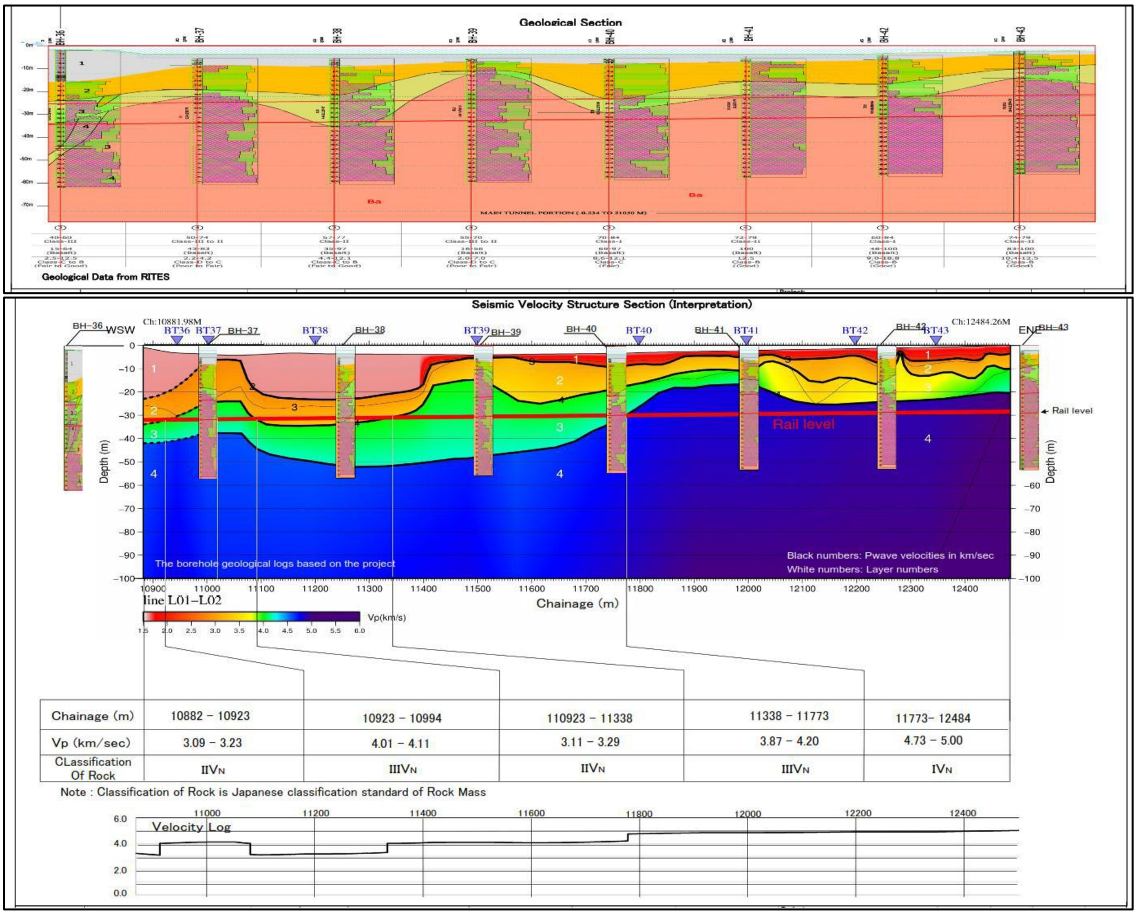


Figure 7.1: Fence diagram showing different structural condition with depth



Chainage (m)	10882 – 10923	10923 – 10994	110923 – 11338	11338 – 11773	11773– 12484
Vp (km/sec)	3.09 – 3.23	4.01 – 4.11	3.11 – 3.29	3.87 – 4.20	4.73 – 5.00
CLassification Of Rock	IIVN	IIIVN	IIVN	IIIVN	IVN

Figure 7.2: Correlation of geophysical information and geological information

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It is reported that there are low and medium to high reflective seabed. The low reflective seabed is interpreted as 'Silty Clay', and medium to high reflective seabed interpreted as 'Sediments with clay and shell fragments'. This thick sediment has obscured the deeper penetration of acoustic signal. the sediment is found in the western part from Ch.11.000 km and between Ch.11.070 km and Ch.11.470 km.

Especially, in the western part from the vicinity of Ch.10.90 km, the layer of "extremely poor" (Layer No. 1) extends to the deep part compared to the geological profile. The Ch. 10.945km point is the intersection of L01 and BT-36, where the velocity structures of both lines generally agree. That is, from the result of SRT, it is concluded that the depth of the lower surface of Layer No. 1 at Ch.10.945km point is approximately 40m. However, the depth of the bottom surface of the layer of "extremely poor" obtained in the geological profile is about -10 to -15 m, which is different from the result of SRT.

In addition, the velocity structure of the area west of Ch.10.945km, from Ch.10.882km to Ch.10.945km, is based on the data analysis of L01 reveals that moderately weathered basalt start at 21.0 m depth.

8. CONCLUSION:

Based on the outcome of Geophysical survey, subsurface stratigraphy along with rock characteristics has been assessed along the seismic profile lines are concluded as follows-

- AS per Japanese classification standard for Mountain tunnel, 2008, the undersea tunnel is completely covered under Volcanic Rock (Basalt) with different degree of weathering hence, the rock type as per Japanese rock classification falls under **"A "category with different rock mass grade.**
- SRT survey along the alignment indicate that the top most layer comprises of sea sediments along with highly to completely weathered rock interpreted with seismic velocity of the order of 1600m/s to 2500 m/s. Thickness of this layer along the alignment seems to varies from 1.17m to 55.20m.
- Between 10.882Km and 10.950Km, thickness of this layer seems to vary from 32m to 55.2m, between 11.100Km and 11.340Km thickness varies from 20m to 22m. In rest of the profile between 11.340Km and 12.484Km, shallow sea sediments have been interpreted. The velocity structure between 10.882Km and 10.945Km in the area is poor and ambiguous.
- Seismic results reveals that the bedrock comprises of basalt is available at depth of 2m to 40m with seismic velocity of the order of 2800m/s to 5100m/s. Lower velocity of the order of 2800m/s to 3500m/s indicates strongly weathered and jointed nature of basalt with Q value varies from 0.2 to 1.0 and RMR is 40 to 50, categorized as **poor** with **rock mass grade " II_N".**
- Whereas, at tunnel grade, seismic velocity of the order of 3300m/sec to 4200m/sec interpreted as slightly weathered to fresh less jointed to basalt, strongly strong to strong in nature with Q value varies from 0.63 to 5.01 and RMR 47 to 51 and rock mass strength (**σc**) varies from 84MPa to 115.5MPa categorized as **very poor to fair** with **rock mass grade "II_N to III_N".**
- Seismic velocity of the order of 4600m/s to 5100m/s interpreted as fresh basalt, strong in nature with Q value varies from 12.59 to 39.81 and RMR 67 to 74. Rock mass strength (**σc**) varies from 129.5MPa to 147MPa categorized as **good** with **rock mass grade "IV_N".**

9. RECOMMENDATIONS:

Based on the outcome of geophysical interpretations of seismic survey, followings recommendations are drawn:-

- Between 10.882Km to 11.000Km, the rock condition is not certain, hence during construction, horizontal drilling may be carried out to confirm the rock condition prior to tunneling with TBM.

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- Beyond 11.00Km, the tunnel alignment passes through a rock mass composed of slightly weathered to fresh basalt, moderately strong to strong in nature, the rock mass, appears to be stable & competent for tunneling and hence no major geotechnical problem anticipated during tunneling.
- It is recommended that the provision of continuous geotechnical monitoring system to be in place for deformation, stress condition and ground water regime during construction of tunnel.
- For design of support system, rock mass characteristics obtained through geophysical methods may be correlated with other geological and geotechnical parameter for better appreciation of design support.

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Polymer Nanocomposite: Self-healing and Carbon dioxide (CO_2) Absorption Potential

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Abstract: *This study examines the synthesis of innovative Polymer Nanocomposites (PNCs) that combineself-healing and Carbon dioxide (CO_2) adsorption properties. By integrating Graphene Oxide (GO) into polymer matrices, we developed nanocomposites that demonstrate improved mechanical strength, self-healing efficiency, and CO_2 capture capabilities. The approach involved using functionalized nanomaterials within polymer matrices to producecomposites that are notably resilient to mechanical damage while actively adsorbing CO_2 from the atmosphere. The reversible bond formation chemistry within these composites enables them to regain structural integrity after damage, due to the interactions between the polymer chains and nanofillers. The addition of nanomaterials also enhances both surface area and reactivity. As the search of green energy alternatives intensifies, interest in GO-modified polymer composites is rising. While fully replacing fossil fuelsremains challenging, effective CO_2 capture and mitigation are critical environmental concerns today. GO and its composites emerge as promising,cost-effective solutions for commercial CO_2 capture. Thus, developing GO polymer nanocomposites that provide both self-healing and self-cleaning functionalities could transform the field. This paper highlights the potential of these novel GO nanocomposites designed for dual purposes of self-healing and CO_2 capture. The findings suggest that these advanced nanocomposites offer significant promise for sustainable materials engineering, aiding in both self- repair mechanisms and climate change mitigation. Future research will aim to optimize material composition andevaluate long-term performance in practical applications.*

Key Words: *Graphene Oxide (GO), polymer nanocomposite; Self-healing; Carbon dioxide(CO_2) Absorption.*

1. INTRODUCTION:

Polymer nanocomposites, a rapidly developing field, have attracted a lot of attention because of their many applications and superior material properties over traditional polymers. Of the many functionalities these advanced materials have been equipped with, self-healing and CO_2 adsorption are particularly noteworthy because of their potential to tackle important structural and environmental issues **[1]**.

Self-healing materials have an inherent ability to recover from damage without the need for outside intervention, increasing the composites' durability and reliability. This feature is essential in fields like electronics, civil infrastructure, and aerospace where maintenance is difficult or expensive. Typically, dynamic covalent chemistry, reversible hydrogen bonding, or micro-encapsulation techniques are used to incorporate self-healing capabilities into polymer nanocomposites. These approaches enable the autonomous repair of micro-cracks and other forms of damage **[2, 3]**.

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Simultaneously with the increasing level of atmospheric CO_2, which is the main reason for global warming, there has been an extensive amount of research conducted on materials that have the ability to effectively capture and absorb CO_2 **[4]**. Polymer nanocomposites, when combined with functionalized nanoparticles, are emerging as promising solutions for capture of CO_2 due to their sustainable nature. These composites are made from polymers, and are combined with nanofillers. These form an alternative because of their chemical functionality, high surface area, and variable porosity. These nanofillers improve the performance and properties of the polymer matrix and are essential in reducing the adverse impacts of climate change since they can be designed to specifically capture CO_2 from the environment **[5, 6]**.
Achieving dual functionality in polymer nanocomposites requires an understanding of the chemistry behind bond formation. In order to create these materials, CO_2 adsorbents and self-healing agents must be carefully included into the polymer matrix. Strong interfacial contacts, such as van der Waals forces, ionic bonding and covalent bonding between the polymer and the nanoparticles frequently promote this bonding. Without sacrificing the composite's mechanical integrity, the effectiveness of these interactions is essential to ensuring the simultaneous implementation of self-healing and CO_2 adsorption capabilities.
This work attempts to investigate the chemistry of bond formation in polymer nanocomposites intended for double function. The characterisation methods, and synthesis methodologies of these materials will be covered. Our goal is to offer a thorough understanding that can direct the creation of polymer nanocomposites for sustainable and resilient applications by understanding the fundamental concepts governing CO_2 adsorption and self-healing.

2. OBJECTIVES:

- Synthesis of polymer nanocomposite.
- Characterization of the synthesized composite.
- Identification of the chemistry behind reversible bonds to investigate the self-healing mechanism and the self-adsorption mechanism.

3. RESEARCH METHOD:

3.1 Materials

Graphite, Sodium Nitrate ($NaNO_3$), Pottassium Permanganate ($KMnO_4$), Hydrochloric acid (HCl), concentrated Sulphuric acid (H_2SO_4), Hydrogen Peroxide (H_2O_2), Poly Vinyl Alcohol (PVA).

3.2 Graphene Oxide (GO) Synthesis

At 0°C, 3.0 g of graphite powder and 2.0 g of $NaNO_3$ were mixed in 70.0 mL of concentrated H_2SO_4. As a precaution, these components were combined in a battery jar cooled to 0°C using an ice bath. At a temperature lower than 20.0°C, 9.0 g of $KMnO_4$ was then gradually added to the mixture. After the ice bath was removed, the solution was let to reach room temperature and then stirred for 15 min. The temperature was maintained below 100°C while 250 mL of distilled water was gradually added. Before adding 400 mL of distilled water for dilution, the aforementioned sample was agitated for 15 minutes. 6 ml of 30.0% H_2O_2 was then mixed into the solution and stirred for 24.0 hr at 600 rpm. The suspension was filtered with watt man filter and washed with 1M HCl to get the metal ions removed and then washed with distilled water till pH became neutral. The brown pasty filtrate of GO was obtained which was mixed in distilled water and ultrasonicated for 1 hr at room temperature to obtain dispersion of GO solution. The above sample was dried for 24 hr for preservation **[7,8].**

3.3 Preparation of PVA/GO Nanocomposites

1g of PVA was dissolved in 20g of distilled water to make 5 wt% PVA solution. For 1 hr, the solution was agitated at 95 °C and 700 rpm. In order to make 1%, 2%, 3%, and 4% GO solutions, 0.01g, 0.02g,

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0.03g, and 0.04g of GO was dispersed into 20 ml of distilled water and ultrasonicated for 1 hr at room temperature. 20 mL of distilled water is combined with 1g of PVA and 0.01g, 0.02g, 0.03g, and 0.04g of GO. The mixture is then agitated for three hours at 700 rpm at 95 °C For the GO filler to properly exfoliate and disperse within the PVA, this solution was sonicated for 30 minutes **[9,10,11].**

4. RESULT and DISCUSSION:

4.1 Fourier Transform Infrared spectroscopy (FTIR)

4.1.1 Characterization of GO

Peaks at 3468 cm−1 in Figure 1 represent (O–H) stretching vibrations, which show the presence of carboxylic (COOH) and/or hydroxyl (OH) groups. The C=O stretching vibrations of carboxylic (COOH) and/or carbonyl (C=O) groups are represented by the peak at 1634 cm−1. A little depression is visible at 1246 cm−1, which can be the result of epoxy group (-O-) absorption **[12,13]**.

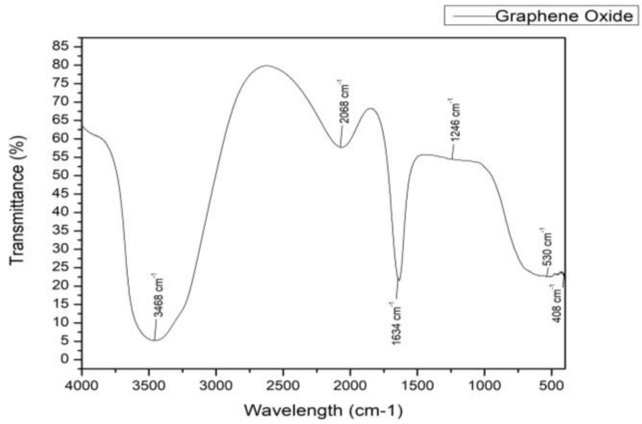

Fig. 1 FTIR of GO

4.1.2 Characterization of PVA and PVA/GO Nanocomposites

Peaks in **Fig. 2** at 3448 cm-1 indicate the (O-H) symmetrical stretching vibrations of the hydroxyl group, the (C=O) stretch of the carbonyl group, the C–H deformation vibration at 1303 cm−1, and the (C–O) stretching of the acetyl groups at 1086 cm−1. The PVA/GO composite's FTIR spectrum in the figure displays peaks at 3462 cm-1 that represent (O-H) stretch of hydroxyl group in both PVA and GO; 1643 cm−1 that represent (C=O) carboxylic and/or carbonyl in both PVA - GO; 1322 cm−1 that represent C-H deformation vibration; 1268 cm−1 that displays a small depression that may be caused by the absorption of epoxy group (C-O-C); and 1096 cm−1 that represent (C–O) stretching of acetyl groups **[14,15]**.

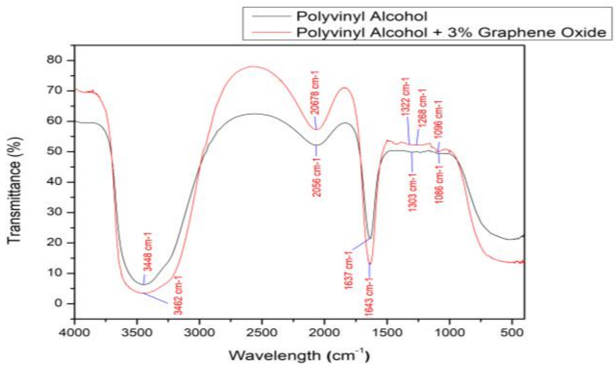

Fig. 2 FTIR of PVA and PVA/GO Nanocomposites

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4.2 Morphological analysis using High resolution transmission electron microscope (HRTEM)

4.2.1 HRTEM of GO

Fig. 3 shows the highly transparent film of GO resulting from stacking nanostructure exfoliation. The image shows wrinkled and folded nature of GO sheets which prove that sheets are thin sheets.

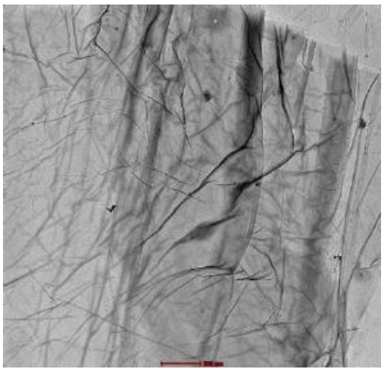

Fig. 3 HRTEM of GO

4.2.2 HRTEM of PVA/GO Nanocomposites

The GO sheets appear as transparent layers with folding and wrinkles because of inherent flexibility of GO, as shown in **Fig. 4**. Since it is polymeric, the PVA component cannot be seen clearly under a HRTEM as GO but is visible as a matrix. However, the way GO sheets are distributed suggests that PVA and GO interacting. A small number of GO stacks are visible, suggesting a strong polymer-nanoparticle interaction. Few agglomerated particles and evenly distributed GO sheets in the image indicate a strong interaction between PVA and GO, most likely due to hydrogen bonding between the hydroxyl groups of PVA and the oxygen-containing functional groups of GO (such as carboxyl and hydroxyl).

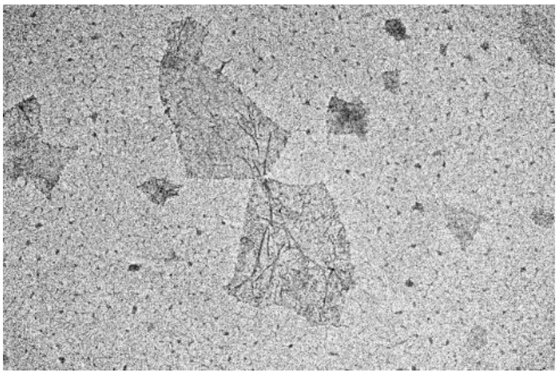

Fig. 4 HRTEM of PVA/GO Nanocomposites

While GO has functional groups such as (-OH), (-COOH) and (-O-), PVA has (-OH) groups in its polymer chains. The PVA chains (-OH) groups have the ability to both donate and take hydrogen. On GO sheets, they are able to develop hydrogen bonds with oxygen atoms in functional groups. By engaging with the -OH groups on PVA, the (-OH), (-O-), and (-COOH) groups on the GO surface can function as hydrogen bond acceptors. Both hydroxyl-hydroxyl and hydroxyl-carboxyl interactions can be formed between the hydroxyl groups of GO and PVA by the hydroxyl groups of PVA. GO has (-COOH), particularly at the margins of the graphene oxide sheets, while PVA has (-OH) along the

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polymer chains. When the (-COOH) on the surface or edges of GO react with the hydroxyl groups (-OH) of PVA through an esterification reaction, an ester bond may be created.

5. CONCLUSION:

The hypothesis is that surface functional groups of GO deposited onto the surface of polymer can undergo reversible interaction to provide self-healing abilities to their interface. The dual interaction of hydrogen bonding and ester bonding between PVA and GO can result in a more stable and well-dispersed composite, which can enhance the self-healing behavior. Since the FTIR study shows the presence of functional groups in these composite that can possibly adsorb CO_2, it will serve as a multifunctional composite. The motive of this research work is to incorporate composite which can develop both hydrogen bond and ester bond. Ester bonds are covalent and stronger, providing better stability and durability under mechanical stress, thermal cycles, and environmental conditions and aid in a more permanent self-healing mechanism. Hydrogen bonds, are weaker and more susceptible to breaking under stress or heat, and contribute to a reversible self-healing mechanism, which can temporarily heal minor cracks or damages but may not provide long-lasting restoration compared to ester bonds. Moreover, the polymers which were selected for this research are biocompatible and non-toxic in nature.

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Towards Intelligent Elderly Care: A Survey on Human Activity Recognition Technologies

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Abstract: *The increasing demands in several fields have sparked interest in human activity recognition (HAR) in recent years. Applications of HAR include security environments for automatic detection of abnormal activity to alert the appropriate authorities, healthcare systems to monitor activities of daily living (ADL). Globally, there are more than 962 million individuals over the age of 60. As people age, their ability to perform daily duties decreases along with their physical activity, which has an impact on their mental and physical health. Few studies have concentrated on the recognition of human activities in elderly individuals, despite the fact that many researchers employ machine learning and deep learning techniques to identify human activities. This paper explores the various technologies employed in HAR, including wearable sensors, vision-based systems, environmental sensors, and smartphones. It also reviews machine learning and deep learning techniques used for activity recognition, with a focus on elderly people. Despite the advancements, challenges such as privacy, accuracy, user compliance, and system integration remain, warranting further research to enhance the reliability and scalability of HAR systems for elderly care.*

Key Words: *HAR, ADL, Hybrid DNN, wireless sensor data mining (WISDM).*

1. INTRODUCTION:

Under the umbrella of computational science and engineering, Human Activity Recognition (HAR) aims to develop methods and systems that can automatically identify and classify human behaviors from sensor data. HAR, is a challenging time series classification task. It involves predicting the movement of a person based on sensor data and traditionally involves deep domain expertise and methods from signal processing to correctly engineer features from the raw data in order to fit a machine learning model.

Human Activity Recognition (HAR) involves several essential steps to identify human activities using sensor data:

1. *Data Collection*: Sensors like accelerometers and gyroscopes are used to collect raw time-series data from wearable devices. This data represents activities such as walking, running, or sitting.
2. *Preprocessing:* Raw data is cleaned by removing noise, and then segmented into fixed-size windows for further analysis. Normalization may also be applied to standardize the sensor readings.
3. *Feature Extraction*: Relevant features are extracted from the preprocessed data to represent the activities. These can be hand-engineered features like mean, variance, or frequency-based features. Deep learning techniques like CNNs or LSTMs may also automatically extract features.

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4. *Model Training:* Machine learning models such as SVMs, Random Forests, or deep learning models are trained using labeled data. The model learns patterns that distinguish different activities during this phase.
5. *Classification*: The trained model predicts activities based on new sensor data. Classification algorithms assign activity labels such as "walking" or "running" to the input data.
6. *Detection*: The system processes real-time data to recognize and detect activities as they occur, allowing for real-time monitoring and alerts for specific actions (e.g., falls).

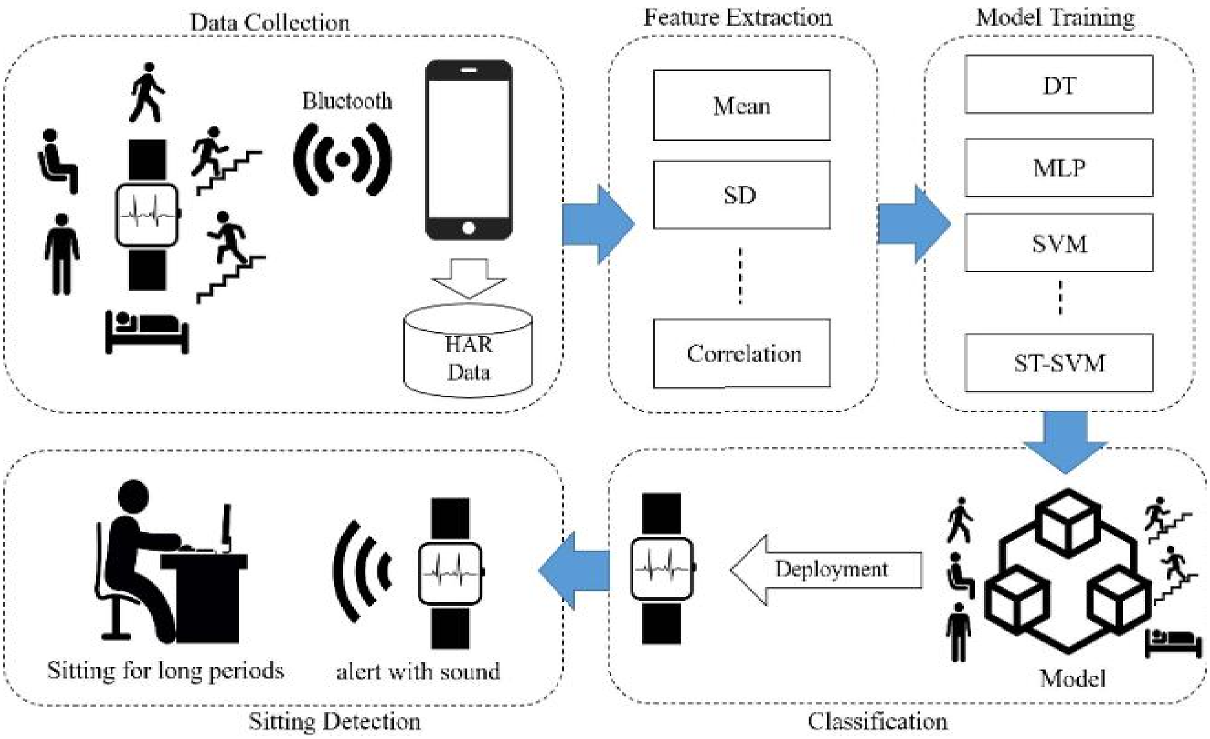

Fig 1 Steps in HAR

In recent years, HAR has drawn a lot of attention for its uses in misbehavior recognition, sports training, medical rehabilitation, smart homes, and fall detection for the elderly. For instance, fall behavior can be identified in order to promptly seek out family assistance when observing the movements of elderly individuals living alone. To accomplish scientific exercise and fitness management, fitness enthusiasts can collect their own activity data by tracking their steps and identifying their level of exercise. Physicians can use gait analysis to diagnose patients with knee problems. Patients with disorders of the lower limbs can have their movement data used to modify the rehabilitation plan during the rehabilitation phase.

Applications of Human Activity Recognition (HAR) include monitoring activities of daily living (ADL) in healthcare systems, identifying anomalous activity automatically in security contexts and alerting appropriate authorities, and enhancing human-computer interaction.

HAR based on wearable sensors has gained popularity in a number of fields, including smart homes, healthcare for the elderly, medical services, improving human interaction with computers, security systems, mechanization in industry, monitoring athlete training, rehabilitation systems, and robot monitoring systems. These fields have benefited from the increasing maturity of computing, machine

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learning algorithms, and neural networks. In data acquisition, it is divided into three categories: wearable sensors, external, non-wearable sensors, and combinations of the first two.

Deep learning methods such as convolutional neural networks and recurrent neural networks have shown capable and even achieve state-of-the-art results by automatically learning features from the raw sensor data. They are commonly applied in the activity recognition space since their accuracy exceeds that of machine learning algorithms.

It is estimated that the number of elderly citizens will increase significantly in the next decade. Health issues among older people are a significant concern in developed countries and developing economies such as Brazil and India. Elderly citizens occupy a large part of health-related facilities due to health issues. In the traditional healthcare system, needs are not entirely met due to the increase in population. On the other hand, medical services are not accessible and affordable. Therefore, HAR is fit for the healthcare of the elderly remotely. This paper illustrates a comparison between already existing approaches of activity recognition for elderly. The paper also explains the challenges in the field of HAR.

2. EXISTING APPROACHES TO HAR:

Several existing approaches for Human Activity Recognition (HAR) for the elderly have been developed to monitor health, improve safety, and support independent living. These methods typically focus on detecting activities, identifying abnormal patterns (such as falls), and ensuring continuous monitoring. Below are the main approaches:

1. Sensor Based Approaches

• Wearable Sensors: Apps such as fitness bands and smartwatches that track movements like sitting, walking, and falling are outfitted with accelerometers, gyroscopes, and heart rate monitors. Because they are movable and offer real-time monitoring, these are frequently utilized in elder care.

• Ambient sensors: Sensors installed in the surroundings, such as pressure mats, infrared, motion detectors, or smart home systems, track a user's movements without requiring them to wear gadgets. They are able to watch what goes on in living areas and identify things like falls and extended periods of inactivity.

• Smartphone-based Sensors: A variety of sensors, including GPS, gyroscopes, and accelerometers, are built into smartphones and can be used to passively track various activities. These gadgets are a popular alternative for monitoring the elderly because of their convenience.

2. Methods Based on Vision

• Cameras: To record the elderly's actions, cameras are positioned around the surroundings. Algorithms for computer vision analyze video footage to identify actions such as standing, sitting, or falling. 3D motion data is also obtained by the use of depth cameras, such as Microsoft Kinect.

• Challenges: This strategy is sometimes limited by privacy issues and high computing costs.

3. Models for Deep Learning and Machine Learning

• Conventional Machine Intelligence: To categorize activities based on attributes taken from sensor data, algorithms such as Support Vector Machines (SVM), Random Forests, Decision Trees, and k-Nearest Neighbors (k-NN) have been used extensively.

• Deep learning: To automatically extract features and model time-dependent activity data, convolutional neural networks (CNNs) and recurrent neural networks (RNNs), particularly Long Short-Term Memory (LSTM) networks, are utilized

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Hybrid Models: Some systems combine traditional machine learning with deep learning for improved accuracy and real-time performance.

4. Multi-modal Approaches: Increasing recognition accuracy requires combining input from several sensors, such as wearables, ambient light, and vision. Wearable sensors, for instance, can record motion, ambient sensors can identify environmental elements, and vision systems can visually record behavior. A richer context is provided for activity recognition by this fusion.

5. Anomaly Detection: In the context of senior care, systems frequently concentrate on identifying anomalous behaviors such as prolonged inactivity or falls. Caregivers can receive real-time alerts when certain incidents are detected. By training machine learning models to recognize departures from the norm, possible emergencies can be handled quickly.

6. Integration with Smart Homes: Interconnected devices (IoT) are used by HAR systems linked into smart homes to smoothly monitor the behaviors of the elderly. Smart appliances, lighting, and thermostats can give users further context for their actions, such as when an older person is cooking or using the restroom. The goals of these systems are to guarantee security and offer support.

7.Context aware systems: These methods modify predictions based on the context of the actions (e.g., time, location). For instance, the system might anticipate a "sleeping" activity if a person is close to a bed at night. By taking into account the user's habits and the surrounding environment, context-aware models increase the accuracy of HAR.

8. Fall Detection: Detecting falls, a key problem for the elderly, requires the integration of specialized models. Accelerometers and gyroscopes are used by these systems to identify abrupt movements linked to falls. When something is identified, the system can sound an alert or call caregivers to come help right away.

3.CHALLENGES IN THE FIELD OF HAR

In systems based on external sensors such as cameras, devices are installed at fixed locations where activity recognition is limited in the camera viewing angle. Two similar activities may not be detectable when we use the camera, and privacy is also violated. In recent years, wearable sensors have been considered in the healthcare system due to cost reduction, ease of use, and continuous monitoring. Wearable technology seems to be a practical step towards achieving the goal of monitoring patients at home. These systems are sophisticated and able to monitor individuals' situations and realize the object of remote monitoring of the elderly. In the HAR system (HARS), the signals obtained through wearable sensors are approximately more desirable than the signals obtained by video cameras, for the following reasons

(i).The environmental and stationary limitations that cameras frequently face are solved by wearable sensors (camera vision limitation resulting from fixed position).

(ii.)The human body can use signals more accurately and efficiently when it has many sensors placed throughout it(iii) While the signals received by the camera may comprise information from other non-target individuals in the scene, the signals received by wearable sensors are intended for a specified purpose.
(iv) Wearable sensors pay closer attention to privacy than do cameras. Video recorders capture every movement of the body as people go about their day to day lives.
(v) Throughout the day, supervisors should remain in the area designated by the cameras' placement and capabilities.
(vi) Additional difficulties with employing video include the expense and complexity of video processing.

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Personal satisfaction, appearance, size and comfort rate, development and support, online data gathering and processing, energy consumption, and privacy concerns are a few of the obstacles associated with wearable sensors.The other challenges found in the field of activity recognition include the following:

a. Data for some emergent or unexpected activities (e.g., accidental fall) is especially hard to obtain, which leads to a challenge called class imbalance.

b. For sensor-based activity recognition, feature extraction is more difficult, because there is inter-activity similarity.(e.g., walking and running). Therefore, it is difficult to produce distinguishable features to represent activities uniquely.

c. Concurrent activities show the third challenge. Concurrent activities occur when a user participates in more than one activity simultaneously, such as answering a phone call while watching TV.

d. Privacy of data can occur as human data recognition systems record user's life continuously.

e. Inertial sensors (accelerometer, gyroscope, and magnetometer) provide measurements with respect to the three orthogonal axes (x, y, z) of the body of the phone; the remaining sensors are orientation-invariant.

Smartphones hold great potential as devices for gathering data that can be used to quantify both established and new risk factors for human populations in an unbiased and repeatable manner. Smartphones in free-living environments can monitor behavioral risk factors, such as sleep, physical activity, and sedentary behavior, among others, by utilizing people's lived experiences.

Significantly, in contrast to certain wearable activity trackers, smartphones are no longer a niche product; rather, they are widely accessible and are being embraced by consumers of all ages in both developed and developing nations. Encouraging results with other portable devices, particularly wearable accelerometers, have further supported their adoption in health research. These devices have shown robust associations between physical activity and health outcomes, such as obesity, diabetes, various cardiovascular diseases, mental health, and mortality.

E-health include remote patient care and management (even for senior citizens), mental and physical rehabilitation, activity assessments, respiratory biofeedback systems, mental stress evaluations, weight training regimens, and real-time monitoring of vision, movement, and posture. People with impairments may be able to live longer, independent lives with the help of an e-healthcare system. Psychological serenity and security for family members and friends can be achieved by using "a simple button for sudden anxiety and fear," "personal alarm devices for the elderly," and "cell phones with a panic button.

4. LITERATURE REVIEW

Human Activity Recognition (HAR) for senior care has been implemented using a variety of deep learning models, each with unique advantages and disadvantages:

i. Convolutional Neural Networks (CNNs): CNNs are useful for short-term activity recognition, such fall detection, because they are good at extracting spatial information from sensor input. They have trouble capturing long-term temporal dependencies, though.

ii. Recurrent Neural Networks (RNNs): RNNs are a neural network model for sequential data, although they are not as good at capturing long-term dependencies and have diminishing gradients. They are helpful in identifying straightforward, ongoing activity.

iii. Long Short-Term Memory (LSTMs): Long-term temporal patterns are well captured by LSTMs, which makes them perfect for tracking activity transitions or extended periods of inactivity. They take a long time to train and require a lot of processing.

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iv. Gated Recurrent Units (GRUs): GRUs are a suitable choice for real-time senior activity monitoring because they offer a good balance between computational cost and performance. They are also quicker and more memory-efficient than LSTMs.

v. Convolutional Recurrent Networks (CRNNs): CRNNs capture both temporal and spatial data by merging CNNs and RNNs; however, this adds complexity to the system, making it appropriate for intricate multi-sensor setups.
vi. Transformers: These models are excellent at capturing long-range dependencies, but their applicability in aging monitoring without enough data is limited by their massive dataset requirements and high computing costs.

[1] presents a unique framework for multi-class wearable user identification that is based on deep learning models for human behavior recognition. Sensory data from wearable devices' tri-axial gyroscopes and tri-axial accelerometers is employed to get enhanced information about users while they undertake different activities. A series of tests were also presented to corroborate this work and illustrate how successful the suggested framework is. The best accuracy for all users was 91.77% and 92.43%, respectively, for the two fundamental models—the Convolutional Neural Network (CNN) and the Long Short-Term Memory (LSTM) deep learning.

Numerous deep techniques have been studied to overcome the difficulties in activity recognition as deep learning has proven to be beneficial in many domains. [2] provides an overview of the most recent deep learning techniques for sensor-based human activity recognition. Initially, the multimodal nature of the sensory data and details on publicly available datasets that can be utilized for assessment in various challenge activities is presented. Next, a novel taxonomy that organizes deep approaches based on obstacles is also suggested. An overview of the present state of research is formed by summarizing and analyzing challenges and challenge-related deep approaches.

HAR is primarily utilized in conjunction with other technologies, such the Internet of Things, to support eldercare and healthcare. Deep learning has enabled automatic extraction of high-level features, which has been applied to enhance HAR performance. Many sectors have also used deep learning techniques for sensor-based HAR. [3] presents a novel approach to capture attributes at different resolutions by combining bi-directional long short-term memory (BiLSTM) and convolution neural networks (CNN) with variable kernel size. This work effectively uses standard CNN and BiLSTM to extract spatial and temporal information from sensor data, and it accurately chooses the best possible video representation. Using UCI datasets, wireless sensor data mining (WISDM) UCI datasets and wireless sensor data mining (WISDM) are employed.

UCI datasets are used for this proposed methodology in which data are collected through diverse methods, including accelerometers, sensors, and gyroscopes. The results indicate that the proposed scheme is efficient in improving HAR. It was thus model found that unlike other available methods, the proposed method improved accuracy, attaining a higher score in the WISDM dataset compared to the UCI dataset (98.53% vs. 97.05%).

In [4] a hybrid approach that combines CNN and LSTM to effectively recognize human activity with higher accuracy is proposed. The main purpose of using this hybrid approach in activity recognition is that human activity is actually the sequence of action that contains temporal information. CNN architecture has the advantage of extracting the discriminative features while LSTM can extracts the temporal information in time-series data. Experiments were conducted on various deep learning models such as CNN, LSTM, Bidirectional LSTM, and CNN-LSTM. This hybrid model demonstrated excellent performance on activity recognition of one-person activity, and it may not be able to perform better in the case of multiple people.

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[5] focuses on providing assistance to elderly people by monitoring their activities in different indoor and outdoor environments using gyroscope and accelerometer data collected from a smart phone.

Conventional Machine Learning and Deep Learning algorithms such as k-Nearest Neighbors, Random Forest, Support Vector Machine, Artificial Neural Network, and Long Short-Term Memory Network are used for human activity recognition. Among all the classification techniques, the proposed Long Short-Term Memory Network gave the best accuracy of 95.04%. However, Support Vector Machine gave 89.07% accuracy with a very low computational time of 0.42 min using 10-fold cross-validation.

Soon the world's population is aging, and their healthcare is essential. It is necessary to consider the dataset based on the activities of the elderly that activities are analyzed to increase the accuracy of recognition and to be able to control the elderly remotely. In this study [6], an architecture for the SHCS was suggested and every facet of it were analyzed, including the activity recognition component. The main obstacles and applications of activity recognition were examined. A comparison was made between the many kinds of macro-methods used in feature extraction, feature selection, and classification. Following the basic classification of the methodologies, a qualitative comparison was carried out using a few key parameters. Additionally, various sensor kinds were classified and investigated and well-known datasets were examined and analyzed.

[7] proposes the Activity Recognition for Activities of Daily Living prediction using Artificial Intelligence. Supervised learning is used to create the prediction model, and Gaussian Naive Bayes (GNB) is chosen as the classifier. The model can effectively and precisely identify the set of ADLs from the gathered raw sensor data, according to the experimental findings and also it has a lower average loss value of 0.461 and a higher average value of overall performance metrics of 0.885 when five various Training: Testing ratios are taken into account, according to the assessment results. The work could be extended for more complicated scenarios involving more residents, places, sensor kinds, and ADLs .

[8] does a thorough analysis of the approaches by utilizing 3D human skeletal input data to identify human activities using deep learning. About 250 results from roughly 70 distinct research on HAR based on deep learning under four different network types—RNN-based, CNN-based, GCN/GNN-based, and Hybrid DNN-based—were generated by the survey.

It also demonstrates how crucial it is to select a solution for the HAR problem; for datasets including a high number of joints in the 3D human skeleton, the method based on projecting the skeleton to the image space and extracting features from it ought to be selected.

Motion or inertial sensors, like the accelerometer and gyroscope that are frequently found in smartphones and smartwatches, can measure the acceleration and angular velocity of bodily movements and be used to train models that can recognize human activities. These models can then be applied to a variety of fields, including biometrics and remote patient health monitoring. Because deep learning-based techniques employ representation learning techniques, which can automatically identify hidden patterns in data and generate optimal features from raw input data generated from sensors without human intervention, they have gained popularity recently for the recognition of human activity. In order to recognize human activity, [9] presents CNN-GRU, a novel hybrid deep neural network model that blends convolutional and gated recurrent units. This model exhibited accuracy that is suggestively better than other state-of-the-art deep neural network models, such as Inception Time and DeepConvLSTM developed using AutoML, and was successfully verified on the WISDM dataset.

Human activity recognition (HAR) benchmark datasets based on accelerometers that were collected while free living have several issues, including inconsistent annotations, a single sensor being used, and non-fixed sensor positioning. [10] makes two contributions. First, it offers the Human Activity Recognition Trondheim dataset (HARTH), which is accessible to the general public. During their

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typical working hours, twenty-two individuals were videotaped for ninety to one hundred minutes using a chest-mounted camera and two three-axial accelerometers affixed to the thigh and lower back. Using the video feed from the camera, experts annotated the data separately and produced a high level of inter-rater agreement (Fleiss' Kappa = 0.96). Twelve activities were tagged by them. The training of seven distinct baseline machine learning models for HAR on our dataset constitutes the second contribution of this paper. A support vector machine was employeed.

5.CONCLUSION AND FUTURE DIRECTIONS

The research focuses on techniques for older people to recognize human activity. Numerous sensor kinds and the problems they present with the data they collect are examined, and a range of deep learning techniques are presented along with an analysis of their advantages and disadvantages. Improving monitoring accuracy and flexibility is a top priority for future research in Human Activity Recognition (HAR) for the elderly. Multimodal data fusion is a viable avenue for improving the recognition of complex activities and transitions by combining data from many sensors, including wearables and cameras. The goal of this strategy is to give a more thorough understanding of the behaviors of the elderly so that everyday activities may be properly monitored.

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CNN-LSTM Hybrid Deep Learning Model for Remaining Useful Life Estimation

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Abstract: *Remaining Useful Life (RUL) of a component or a system is defined as the length from the current time to the end of the useful life. Accurate RUL estimation plays a crucial role in Predictive Maintenance applications. Data driven approaches for RUL estimation use sensor data and operational data to estimate RUL. Traditional regression methods, both linear and non-linear, have struggled to achieve high accuracy in this domain. Although Multilayer Perceptron (MLP) has been applied to predict RUL, it cannot learn salient features automatically, because of its network structure. While Convolutional Neural Networks (CNNs) have shown improved accuracy, they often overlook the sequential nature of the data, relying instead on features derived from sliding windows. Since RUL prediction inherently involves multivariate time series analysis, robust sequence learning is essential. In this work, we propose a hybrid approach combining Convolutional Neural Networks with Long Short-Term Memory (LSTM) networks for RUL estimation. Although CNN-based LSTM models have been applied to sequence prediction tasks in financial forecasting, this is the first attempt to adopt this approach for RUL estimation in prognostics. In this approach, CNN is first employed to efficiently extract features from the data, followed by LSTM, which uses these extracted features to predict RUL. This method effectively leverages sensor sequence information, uncovering hidden patterns within the data, even under multiple operating conditions and fault scenarios. For comparative purpose, we also evaluate the performance of various machine learning algorithms including Gradient Boosting, MLP, CNN, LSTM and Random Forest on the NASA CMAPSS dataset, which includes sensor data linked to the RUL of various jet engines. Our results demonstrate that the hybrid CNN-LSTM model achieves the highest accuracy, offering a superior R^2 score compared to the other methods.*

Model	RMSE	R2 Score
Linear Regression	43.18	0.46
Random Forest	6.68	0.42
XG Boost	17.35	0.65
Multilayer Perceptron	4.51	0.52
CNN	16.82	0.79
LSTM	15.93	0.75
CNN + LSTM	**13.34**	**0.86**

Key Words: *Predictive Maintenance, CNN, LSTM, Remaining Useful Life, MLP*

1. INTRODUCTION

Remaining Useful Life (RUL) of a component or a system is defined as the length from the current time to the end of the useful life [2]. Accurate RUL estimation plays a crucial role in Predictive Maintenance applications. If we can accurately predict when an engine will fail, then we can make

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informed maintenance decision in advance to avoid disasters, reduce the maintenance cost, as well as streamline operational activities, aligning with the principles of industry 4.0 [1, 10]. In general, two types of methodologies are used for RUL estimation: model-based approaches and data-driven approaches. Model-based methodologies build physical failure models for degradation, such as crack, wear, corrosion, etc [1]. Physical models are very useful to solve RUL problem in use-cases where there is no enough failure data available. In such cases, we can induce failures within physical models, augment the actual data with physical model failure data and learn models for RUL estimation. However, such physical failure models are very complex and difficult to build, and physical models for many components do not exist. On the other hand, data-driven methods that employ sensor and operational status data to estimate RUL are more advantageous and economical for equipment with a sufficient number of failures.

In this paper, we conducted a thorough analysis of the data driven approach for RUL estimation. Traditional data driven approach utilizes both linear and non-linear regression techniques to estimate RUL, however they have difficulty achieving high accuracy in this field. Although Multilayer Perceptron (MLP) has been applied to predict RUL, it cannot learn salient features automatically, because of its network structure. However, it is extremely challenging, if not impossible, to accurately predict RUL without a good feature representation method. It is thus highly desirable to develop a systematic feature representation approach to effectively characterize the nature of signals related to the prognostic tasks.

Recently deep learning models are highly popular due to its ability to learn automatically the hierarchical feature representation from raw data. The deep learning architecture contains sequence of layers, each of which applies a non-linear transformation on the outputs of the previous layer. This allows the data to be represented by a hierarchy of features with varying levels of detail. The widely known deep learning models are Convolutional neural network (CNN), Recurrent Neural Network (RNN), Auto-encoders and Transformers.

Convolutional neural network adapted from deep learning architecture uses different processing units such as convolution, pooling, activation etc., to effectively capture local features from the global data [27]. The deep architecture allows multiple layers of these units to be stacked, enabling the model to identify signal characteristics at different scales. Therefore, the features extracted by CNN are task dependent and non-handcrafted. Moreover, these features offer more predictive power, as the CNN is trained under the supervision of target values.

Recurrent Neural Network, a class of deep learning architectures is well suited for modelling time sequence data [25]. However, RNN is known to suffer from long-term temporal dependency problem, as the gradients propagated over multiple stages tend to either vanish or explode. Long Short-Term Memory Network (LSTM) is a form of RNN network for sequence learning tasks [5, 21] and has achieved remarkable success on speech recognition and machine translation. LSTM addresses the long-term time dependency problem of RNN by controlling information flow using input gate, forget gate and output gate. Long term memory retention is essentially their default mode of operation [23].

While Convolutional Neural Networks have shown improved accuracy, they often overlook the sequential nature of the data, relying instead on features derived from sliding windows. Since RUL prediction inherently involves multivariate time series analysis, robust sequence learning is essential.

Therefore, a novel hybrid architecture combining CNN with LSTM networks for RUL estimation is developed in this paper. Although CNN-based LSTM models have been applied to sequence prediction tasks in financial forecasting, this is the first attempt to adopt this approach for RUL estimation in prognostics. In the proposed architecture for RUL estimation, one dimensional convolutional filters in the initial layer are applied to all the sensor data at each time stamp followed by LSTM layers applied temporally over the time series and the final neural network regression layer employs squared error loss function. In this approach, the CNN layer efficiently extracts features from the data, followed by LSTM layer, which uses these extracted features to predict RUL. This method

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effectively leverages sensor sequence information, uncovering hidden patterns within the data, even under multiple operating conditions and fault scenarios.

Data-driven approaches involve several key steps, including data collection, data wrangling, exploratory data analysis, feature engineering, and subsequent model preparation and evaluation. In the experiments, the proposed CNN with LSTM based approach for RUL estimation is compared with existing regression-based approaches in the CMAPSS public data set. The results clearly demonstrates that the proposed approach accurately predicts RUL than existing approaches significantly.

The following sections of this article are organized as follows: Section 2 explains the background and related work. Section 3 outlines the CNN LSTM hybrid Deep learning architecture. Section 4 describes the methodology, and Section 5 discusses the experimental results. Finally, Section 6 addresses the future work and conclusions.

2. Related Work :

In this section we primarily focus on regression-based machine learning approaches for RUL estimation. There exist two main categories of machine learning-based techniques, the first one is supervised approaches where the failure information exists in the dataset and the second one is unsupervised approaches, where there is only process information, and no failure-related information exists [30]. Supervised machine learning methods have been increasingly applied for RUL estimation in the various areas such as medical devices [12], automated teller machines (ATM) [13], electric propulsion systems [14, 29], rolling-element bearings [15], computer workstations [16], automobiles [28] and industrial machines [29].

The existing algorithms in the literature for RUL estimation are either based on multivariate time series analysis or damage progression analysis [3, 18, 19, 20, 26]. Many approaches utilize conventional machine learning models such as support vector machines (SVM) [17] and decision tree-based models [12, 13]. An important benefit of these models is their interpretability, as they help identify key factors contributing to machine breakdowns.

In [4], a deep convolutional neural network model is used to estimate RUL. In the proposed architecture, convolution filters in the initial layer are two dimensional which is applied along the temporal dimension over the multi-channel sensor data and final neural network regression layer employs squared error loss function to incorporate automated feature learning from raw sensor signals in a systematic way. Li et al. [32] developed a multi-scale deep convolutional neural network (MS-DCNN) and used the min-max normalization with the MS-DCNN algorithm for RUL prediction. They compared the performance of their model with other state-of-the-art models and showed that the new model provides promising results on the NASA C-MAPSS dataset [26].

In [5], LSTM network model is utilised for the accurate RUL estimation. Due to the inherent sequential nature of sensor data, LSTM is well suited for RUL estimation. In this approach, multiple layers of LSTM cells in combination with feed forward layers to uncover hidden patterns in sensor data at various stages of degradation.

A set of turbo engine run-to-failure datasets is provided by NASA [26, 31], and the data is used in many research papers to predict the RUL. Ramasso and Saxena [24] published a survey on prognostic methods used for the NASA turbo engine datasets and divided the prognostic approaches into three categories. The first category is the use of functional mappings between the set of inputs and RUL. For the first category, they reported that the dominant underlying machine learning algorithm is artificial neural networks (ANNs) [22]. The second category of techniques is the functional mapping between the health index and RUL. The third category is similarity-based matching techniques. Benchmarking of prognostic methods has been conducted on the NASA turbo engine dataset, and it was shown that most of the studies use a health index to map between input features and the RUL.

In several studies, indirect measurements of RUL are used in place of direct observations. Because of this, estimating the RUL frequently involves the use of the health index (HI) concept [34]. Rather than directly predicting the RUL, a machine learning model is trained to forecast the HI of a turbo

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engine for each cycle. Ziqiu et al. [33] used the notion of HI and the Multilayer Perceptron (MLP) machine learning method in combination with feature normalization, Principal Component Analysis (PCA), and feature selection approaches to estimate the RUL. They also used the NASA CMAPSS dataset to assess the performance of their model.

In our study, we adopt to the supervised machine learning approach for the estimation of RUL using a deep CNN combined with LSTM architecture. In consistent with other models, we thoroughly investigate the effectiveness of this innovative model and compare its performance against other established machine learning algorithms using the NASA turbo engine datasets.

3. CNN LSTM Hybrid Deep Learning Architecture for RUL Estimation

This section presents the proposed architecture of CNN LSTM hybrid deep learning model for RUL estimation. CNN have great potential to identify the various salient patterns of sensor signals. However, in RUL estimation we confront with multiple channels of time series signals, in which the traditional CNN cannot be used directly. Hence, we hybrid the LSTM network to capture temporal dimension. The LSTM module receives the output from the CNN module and processes it sequentially to capture long-term dependencies and temporal patterns. It uses multiple layers of LSTM cells in combination with standard feed forward layers to discover hidden patterns from sensor data. The overview block diagram of the CNN LSTM architecture is shown in the Fig. 1.

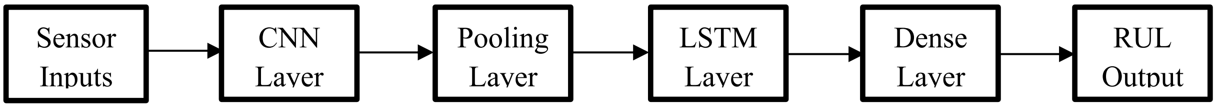

Fig. 1: Block Diagram of proposed CNN LSTM hybrid architecture

3.1. Convolutional Neural Network

In our work, we have limited the architecture to a single CNN layer, which consists of one convolution layer followed by a pooling layer. This simplified structure is sufficient for this task, which helps to reduce computational complexity. In the convolution layer, the input sensor data at a specific time instant is processed using one-dimensional convolutional kernels. We apply 64 one dimensional convolution filters and relu activation function. In the pooling layer, we use one dimensional max pooling without overlapping, where the input feature maps are divided into non-overlapping regions, and for each sub-region, the maximum value is taken as the output.

3.2. LSTM Model

LSTM cell uses memory cells and three gates: the forget gate determines what information to discard, the input gate controls new information added, and the output gate manages how much of the cell state is used for output as shown in Fig. 2. This structure allows LSTMs to effectively retain important information over time, making them suitable for tasks like time-series prediction and sequence modeling. Hence, we split the dataset into multiple fixed length time series data of length 30 and applied to the model.

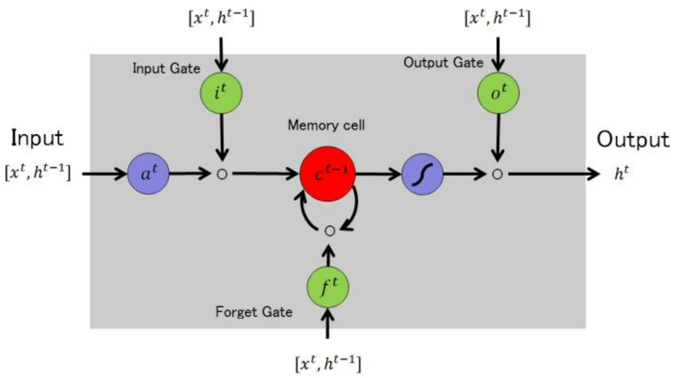

Fig. 2: LSTM Cell

ISBN: 978-81-976827-5-9

3.3. CNN LSTM Architecture

The CNN module processes the input data and extracts relevant spatial features through convolutional layers. These layers employ filters to capture local patterns within the input sequences, enabling the model to learn hierarchical representations of the data. The LSTM module receives the output from the CNN module and processes it sequentially to capture long-term dependencies and temporal patterns. In the proposed CNN LSTM hybrid architecture shown in Fig. 3, leverages the strengths of both CNNs and LSTMs to capture spatial patterns and long-term dependencies in sequential data. We combined the 1D convolution layer followed by pooling layer with multiple LSTM and fully connected layers. CNN takes the input sensor data at each time step and its output is passed to LSTM layer. The LSTM output is then fed into fully connected layers, and the final regression layer predicts the RUL.

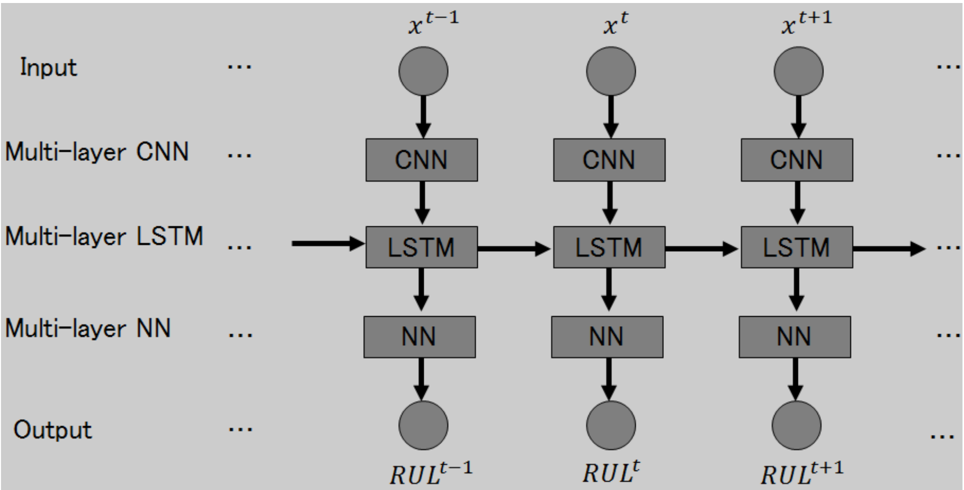

Fig. 3: CNN LSTM Hybrid Architecture Model

3.4. Model Evaluation

In order to evaluate the performance of a RUL estimation model on the test data, *Root Mean Square Error* (RMSE) Eq. (1), gives equal penalty weights to the model when the estimated RUL is smaller than true RUL and when the estimated RUL is larger than true RUL.

$$\mathrm{RMSD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - x_0)^2}. \qquad (1)$$

Eq. (2) is *R^2 Score*, which is also widely used as an evaluation metric for the estimation of RUL. It represents the proportion of variance in the target variable that can be explained by the independent variables in the model. Mathematically, the R^2 score is defined as:

$$R^2 = 1 - \frac{SS_{\mathrm{res}}}{SS_{\mathrm{tot}}} \qquad (2)$$

Where SS_{res} is the sum of squared residuals (the differences between the observed and predicted values), and SS_{tot} is the total sum of squares (the differences between the observed values and their mean). R^2 score of 1 indicates that the model perfectly explains all the variability in the target variable and an R^2 score of 0 suggests that the model fails to explain any variability and performs no better than a simple mean-based prediction.

In literature, *scoring* function is given to measure the quality of the models [4, 5]. Eq. (3) shows the definition of scoring function.

$$S = \begin{cases} \sum_{i=1}^{n}(e^{-\frac{h_i}{13}} - 1), \text{when } h_i < 0 \\ \sum_{i=1}^{n}(e^{\frac{h_i}{10}} - 1), \text{when } h_i \geq 0, \end{cases} \qquad (3)$$

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Where n is total number of samples in the test set, hi = $RUL_{est,i}$ - RUL_i, RUL_i is true RUL for the test sample 'i'. Eq. (3) gives different penalty when the model underestimates RUL and when the model overestimates RUL. If estimated RUL is less than the true RUL, the penalty is smaller, because there is still time to conduct maintenance and it will not cause significant system failure. If estimated RUL is larger than true RUL, the penalty is larger, because under such estimation, the maintenance will be scheduled later than the required time and it may cause system failure.

4. Methodology :

This section outlines the key steps taken before the modeling phase. It starts with preparing features and target variables, followed by data analysis to explore relationships between variables using visualizations. Data pre-processing is then discussed, including filtering and normalization. Feature engineering is applied to create or modify features for better predictive power. Finally, techniques like Principal Component Analysis (PCA) and feature selection are used to remove redundant or irrelevant features.

4.1. Data Preparation

The dataset comprises multiple multivariate time series sensor data, which is divided into training and test subsets. Each time series is from a different engine i.e., the data can be considered to be from a fleet of engines of the same type. Every engine has varying degrees of initial wear and manufacturing variance in the beginning. This variation and wear are regarded as normal and do not indicate a malfunction. The data is contaminated with sensor noise. The engine is operating normally at the start of each time series, and develops a fault at some point during the series. In the training set, the fault grows in magnitude until system failure. In the test set, the time series ends some time prior to system failure. The objective is to predict the number of remaining operational cycles before failure in the test set, or in other words the number of cycles the engine will continue to operate after the last recorded cycle. In addition to that a vector of true RUL for the test set is also provided in the dataset.

CMAPSS Dataset

The dataset contains 26 numerical features, where each row represents a snapshot of data collected in a single operational cycle across 100 different engines. Sensor data is recorded during each engine power cycle and is gathered for one hundred distinct engines. Engine ID, Time in Cycles, Settings 1, 2, 3, and the remaining columns all contain sensor data. There is no formal definition of the specifics of any sensor data.

Target RUL

The target variable is not explicitly provided in the dataset, instead it is calculated by subtracting the number of cycles from the engine's maximum cycle. This leads to a new column labelled "Remaining Cycles," which becomes the target variable and it represents the Remaining Useful Life of the engine. The health of a system generally degrades linearly along with time. In practical applications, a component's degradation is minimal at first and grows as it gets closer to its end of life. A piece-wise linear RUL target function was proposed in [3, 4], in order to better reflect the changes in Remaining Useful Life over time. This function sets a maximum RUL and then begins linear degradation at a specific usage level as shown in the Fig. 4. We set the maximum limit as 130 time cycles for all the engines.

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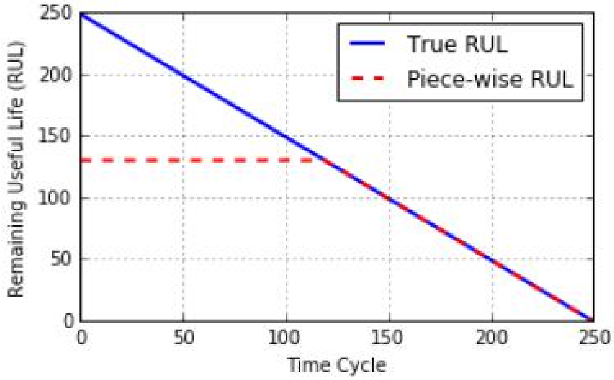

Fig. 4: Piece-wise RUL of the Data Set (Piece-wise maximum RUL is 130-time cycles)

4.2. Data Analysis

The Fig. 5 shows the sensor readings for one of the engines over the course of its lifetime. The sensor values are displayed on the Y-axis, while the power cycles are represented on the X-axis. From the graph, it can be observed that sensors such as Sensor 3, Sensor 4, Sensor 8, Sensor 9, Sensor 13, Sensor 19, Sensor 21, and Sensor 22 maintain constant readings throughout their lifecycle. Since these constant sensor readings do not contribute any predictive value, these features can be safely removed from the dataset.

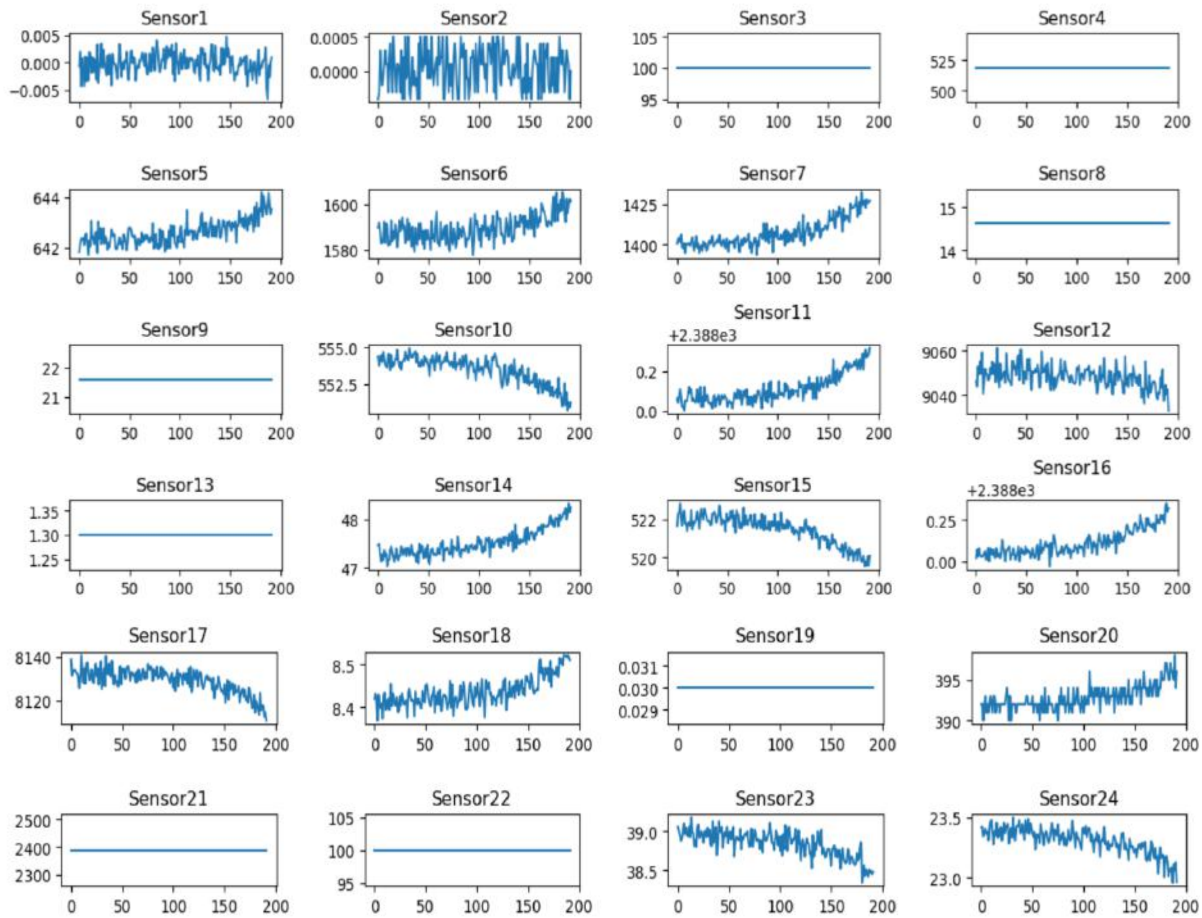

Fig 5: Time series sensor data of one of the Engines

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The distribution of each sensor data in the dataset varies significantly. As per Fig. 6, some sensors, such as 1, 5, and 6, exhibit a normal distribution and the remaining sensors display skewed distributions, either to the right or left. This diverse range of data distributions necessitates tailored pre-processing techniques to ensure optimal model performance.

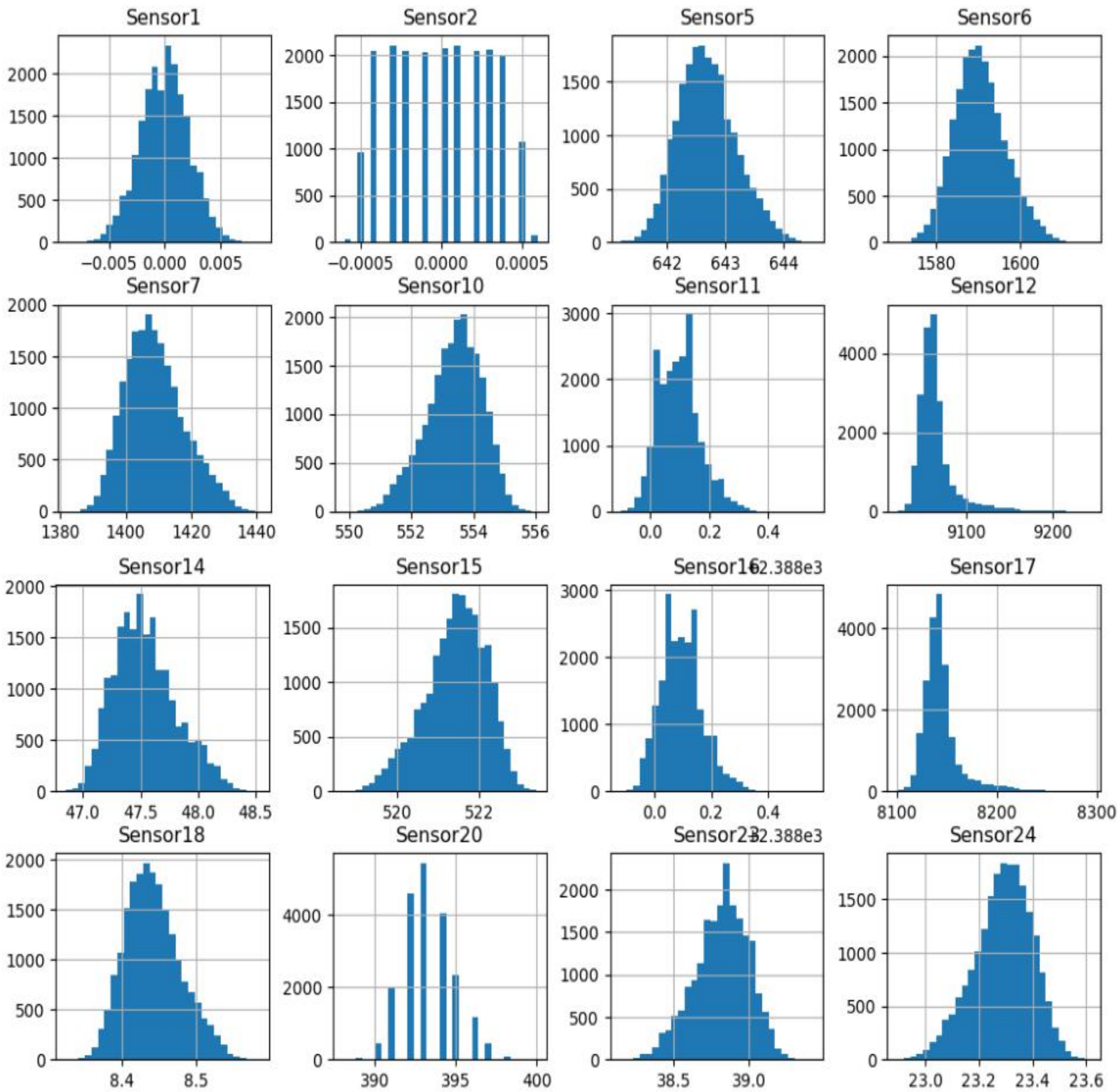

Fig. 6: Frequency Distribution Plot for Sensor Data

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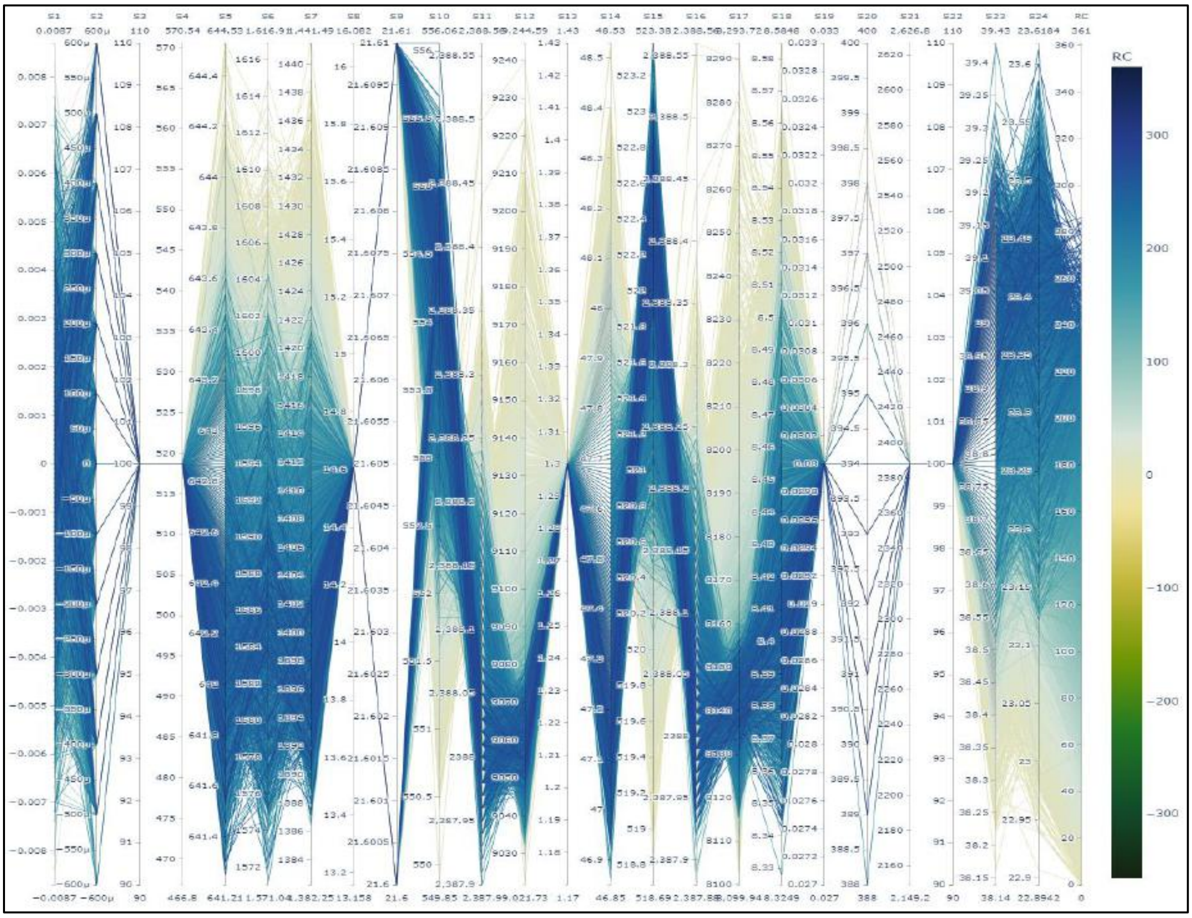

Fig. 7: Parallel Coordinates plot for CMAPSS Dataset

Parallel Plot [11] is a type of data visualization used to explore and analyse multi-dimensional data. Parallel plot applied to the dataset is displayed in Fig. 7, where dark blue lines represent observations with more remaining cycles, while yellow lines indicate lower remaining cycles. The sensor values tend to be more consistent and grouped together in the early cycles, which are represented by dark blue lines and suggest stable operation. Sensor readings begin to differ as the engines get closer to the middle of their lives; this is a sign of both performance discrepancies and the onset of defects. The sensor values exhibit a substantial divergence, suggesting wear and degradation, as the sensor approaches its end of life, indicated by yellow lines.

The sensor data for all engines is illustrated in the Fig. 8. The green dots in this graphic show the exponential moving average of the sensor data for one engine throughout the course of its lifetime, while the red points show the points at which each engine fails. With the exception of Sensors 1 and 2, it is clear from the figure that the majority of sensors are able to differentiate between the engine's normal operating circumstances and failure scenarios. As a result, the characteristics associated with Sensors 1 and 2 can be disregarded for additional examination. Furthermore, some sensor readings are positive correlation with degradation and while others show a negatively correlation.

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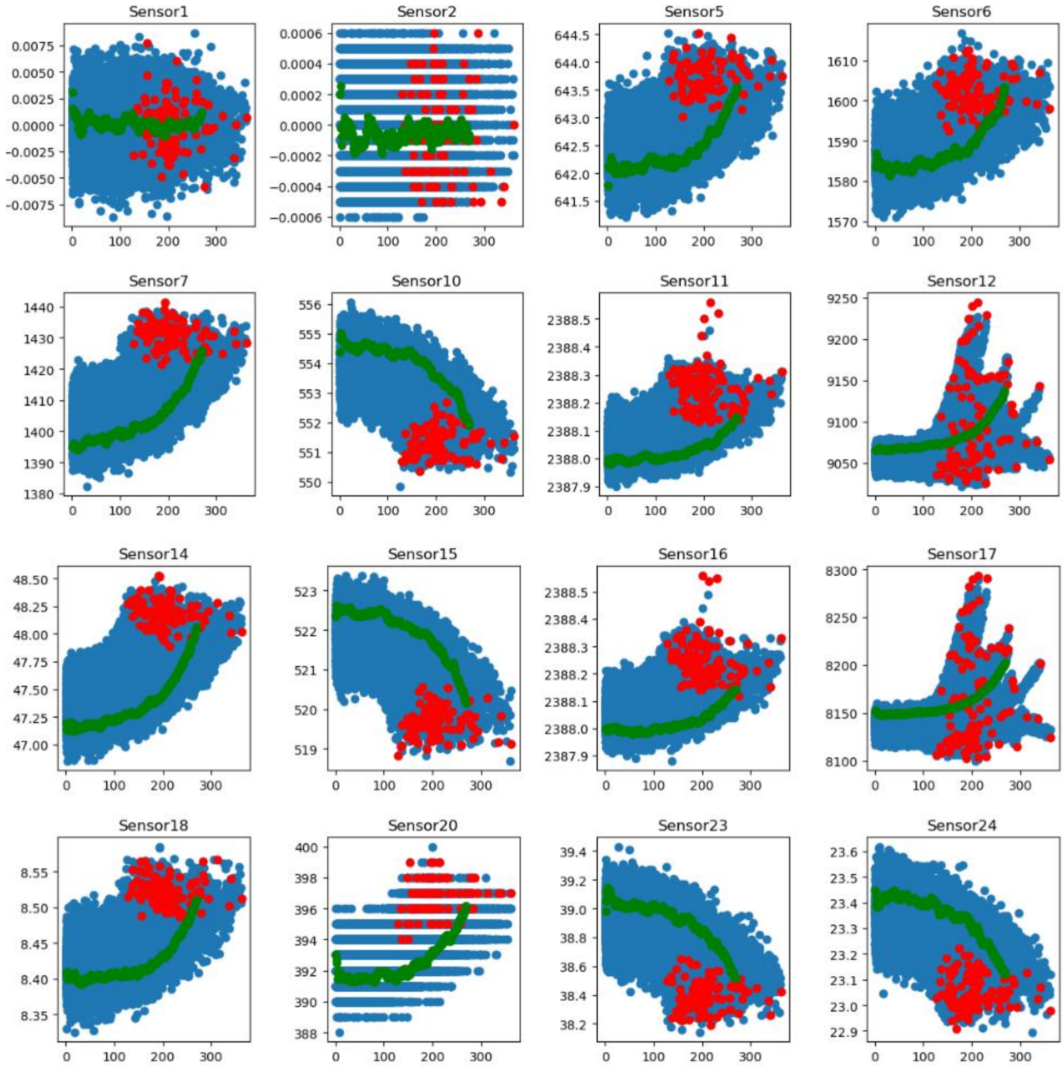

Fig. 8: Scatter plot representation of sensor data of all engines

4.3. Data Pre-processing

Data preprocessing is essential before modeling as it enhances data quality, ensuring that the input data is accurate, consistent, and relevant. The techniques such as cleaning and standardization rectify errors and inconsistencies, leading to more reliable models.

4.3.1. Data Filtering

The sensor data in the dataset are noisy and sporadic, necessitating the application of smoothing filters to improve data quality. Two widely used smoothing techniques such as Simple Moving Average (SMA) and Exponential Moving Average (EMA), were applied with various weights to determine the most effective method. Upon evaluation, EMA with an alpha value of 0.1 visually outperformed other configurations. Consequently, EMA with this alpha value was selected and applied to the sensor data, resulting in a smoother and more reliable data. Fig. 9 shows a visual comparison of raw sensor data and the exponential mean of sensor data with alpha = 0.1. In the raw data, the data points are far more scattered than their corresponding exponential mean. Therefore, the modified data may provide better results for the model than using the raw sensor data directly.

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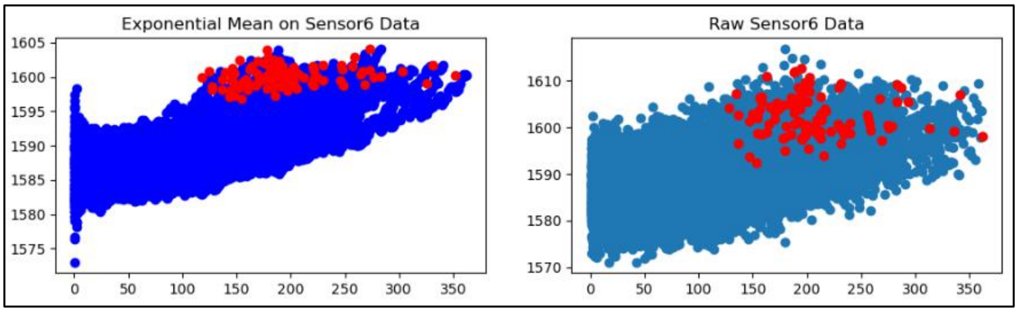

Fig. 9: Comparison between Raw sensor data and exponential moving averaged sensor data

4.3.2. Data Standardization

Since the value range is substantially different in different variables, it can be difficult to find the optimal point for the cost function. Therefore, the training and testing datasets need to be normalized. There are two widely used methods for normalization, which are Z-scores as specified in Eq. (4) and min-max-scale as specified in Eq. (5). Both methods are applied, and the one with the best evaluation result is selected.

$$x' = \frac{x - \text{mean}(x)}{\text{std}(x)} \quad \textbf{(4)}$$

$$x' = \frac{x - x_{min}}{x_{max} - x_{min}} \quad \textbf{(5)}$$

4.4. Feature Engineering

In the dataset, some features exhibit constant values throughout all observations, resulting in zero variance. These features are removed in the previously discussed data analysis section, as they provide no meaningful insight into the relationship between the input variables and the target variable. In addition to that, feature transformation can be applied to further optimize the dataset. By removing or transforming such features, the model's performance can be significantly improved.

4.4.1. Principal Component Analysis

As part of feature engineering, Principal Component Analysis (PCA) was applied to reduce the dimensionality of the high-dimensional sensor data. PCA projects the data onto orthogonal axes, retaining the most significant features. The cumulative explained variance ratio, shown in Fig. 10, indicates that the first two components capture around 70% of the variance, while 12 components account for nearly 99%. Therefore, the data dimension can be reduced from 24 to 12 with minimal loss of information.

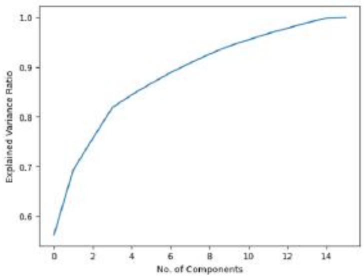

Fig. 10: Explained Variance Ratio of Principal Components

The first, second, and third principal components are studied extensively as they represent 75% of the dataset's variance. Fig. 11 represents the scatter plot for the complete dataset, where green dots represent the starting points of the engine cycles, and orange dots represent the failure points. It becomes evident from the scatter plot that thresholding the first principal component can effectively determine the failure point of all engines, irrespective of the other principal components.

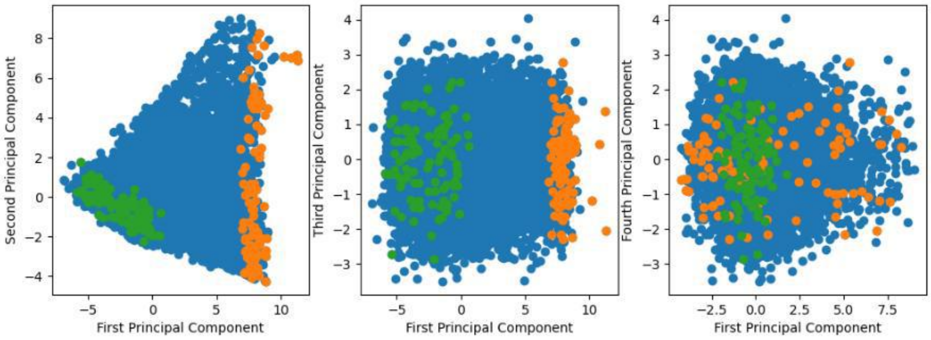

Fig. 11: Correlation plot of first 3 principal components

4.4.2. Multi collinearity Analysis

When working with multiple numerical features in a dataset, it is essential to analyse the correlation between these features. Highly correlated features can introduce redundancy, biasing the model and ultimately reducing the accuracy of predictions. When two or more features provide similar information, the model may overemphasize their contributions, leading to overfitting or skewed results. From the heat map shown in Fig. 12, it is evident that lot of features are highly correlated and it can lead to multi collinearity problem. Multicollinearity refers to the situation where two or more features in a dataset are highly correlated, which can negatively impact the performance of machine learning models. Therefore, it is crucial to select features that contribute the most to the model's performance while minimizing redundancy.

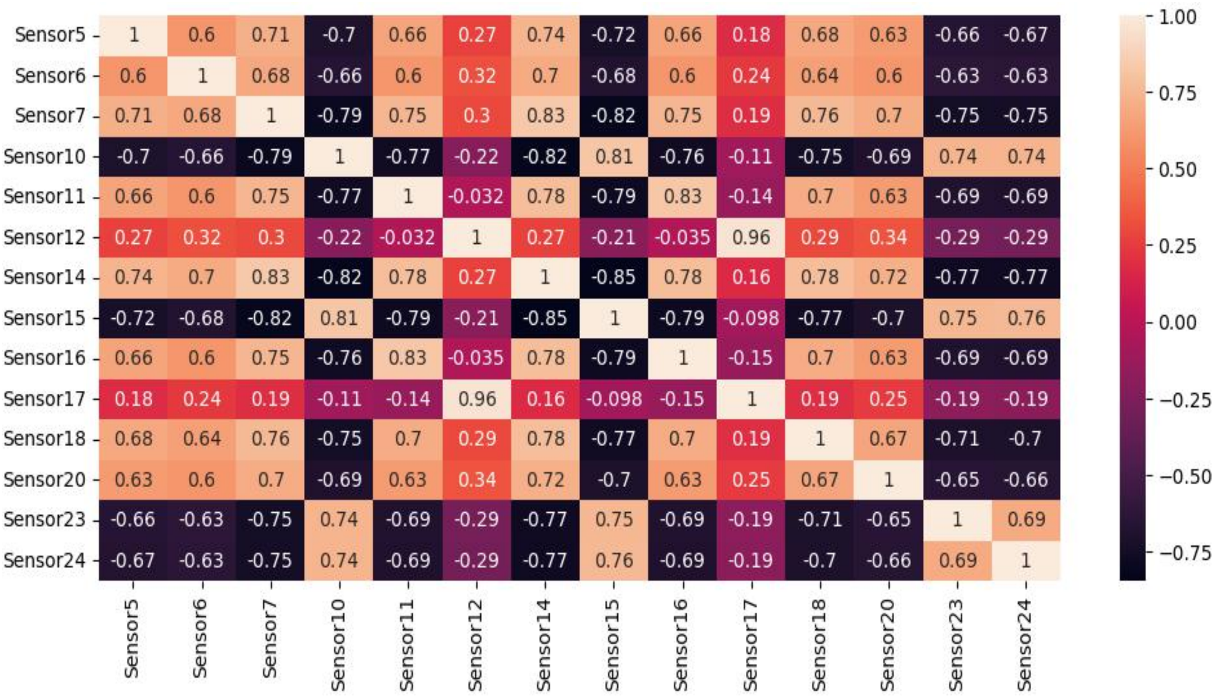

Fig. 12: Heat map of the features in CMAPSS dataset

4.4.3. Feature Selection

From the Fig. 13, it is evident that the first principal component can be segregated to indicate failure, which helps the model in tuning the remaining useful life (RUL). Therefore, the first principal component is included as an additional feature for model development. This inclusion enhances the

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model's ability to predict RUL more accurately by leveraging the significant variance captured by the first principal component.

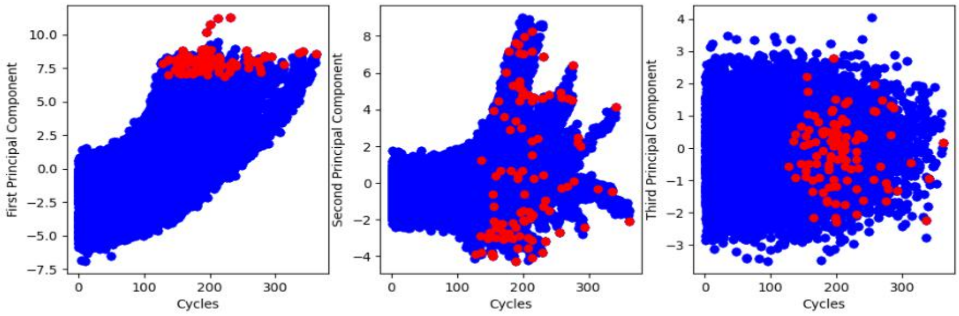

Fig. 13: Principal Components Vs Cycles

To tackle the issue of multicollinearity, as discussed in the previous section, we applied the Select K Best algorithm. This algorithm ranks all the features according to a specified statistical criterion and selects the top K features that are most significant for predicting the target variable. Fig. 14 clearly shows that the logarithmic F-scores of Sensor1 and Sensor2 are significantly low, indicating their minimal importance. Therefore, these sensors can be removed due to their limited contribution.

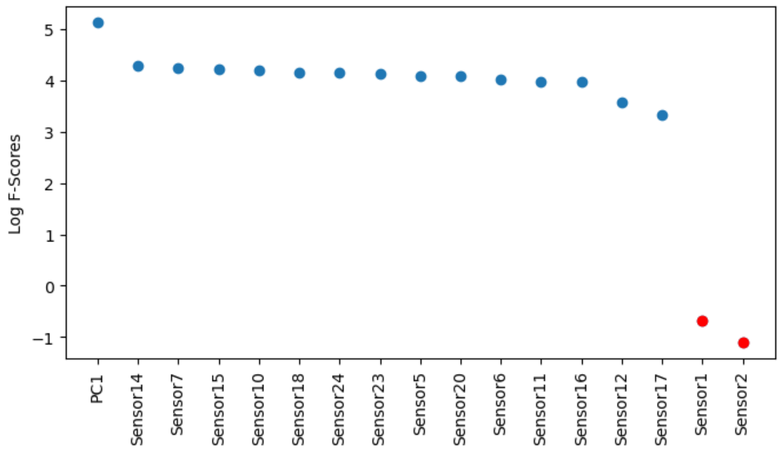

Fig. 14: Features ranked based on F-scores by Select K Best Algorithm

5. Experiments and Results

In this section, we have performed extensive experiments for comparison of the proposed CNN LSTM based deep learning model with traditional regression algorithms such as Linear Regression, Random Forest [6], and state-of-the-art algorithms, including Multi-layer Perceptron (MLP) [9], XGBoost [7, 8] and LSTM on the CMAPSS data set. The hyper parameters of all the techniques, are chosen using standard 5-fold cross-validation procedure, where we tune their parameter values for training these models and choose their final values that give the best results.

The hyperparameter tuning for the Random Forest, XG boost, MLP are performed as shown in the Table 1 and Table 2.

Table 1: Hyperparameter Tuning for Random Forest

Hyperparameter	***Description***	***List of Values***	***Best Estimator***
n_estimators	No. of Trees	[100,200,300]	**300**
max_depth	Maximum depth of trees	[6,8,10,12,14]	**6**
min_samples_leaf	Minimum of samples for leaf	[4,6,8,10]	**4**
ccp_alpha	Tree pruning factor	[0,1,2]	**0**

Table 2: Hyperparameter Tuning for XG Boost

ISBN: 978-81-976827-5-9

Hyperparameter	***Description***	***List of Values***	***Best Estimator***
learning_rate	Learning Rate	[0.05,0.1,0.2]	**0.1**
n_estimators	No. of Trees	[70,100,200,300]	**70**
max_depth	Maximum depth of trees	[3,4,5]	**3**
min_child_weight	Minimum sum of instance weights	[70,100,150,200]	**200**

Table 3: Hyperparameter Tuning for MLP

Hyperparameter	***Description***	***List of Values***	***Best Estimator***
learning_rate	Learning Rate	[0.05,0.1,0.2]	**0.1**
n_layers	No. of layers	[3,4,5,6]	**5**
layer_sizes	No. of neuron in layers	[8.16.64.32.8, 16.32.64.32.16, 32.64.64.32.16]	**32.64.64.32.16**

The performance of the previously discussed machine learning algorithms are compared with the performance of the proposed model and the results are shown in Table 4. From the table, it is evident that the proposed hybrid CNN-LSTM model demonstrates the better RMSE and offering a superior R^2 score compared to the other methods.

Table 4: Performance comparison on C-MAPSS dataset

Model	***RMSE***	***R^2***
Linear Regression	43.18	0.46
Random Forest	6.68	0.42
XG Boost	17.35	0.65
MLP	4.51	0.52
LSTM	15.93	0.75
CNN LSTM	**13.34**	**0.86**

6. Conclusion and Future work :

We proposed CNN LSTM based deep learning approach for RUL estimation and we showed its benefits by taking sequence information when estimating RUL. Our experiments on C-MAPSS dataset showed that our proposed model outperforms other approaches and gives the best performance in RUL estimation. In addition to that, the work involves the entire lifecycle of predictive maintenance, starting with data collection, followed by comprehensive data preparation and pre-processing stages to ensure data quality and consistency. Feature scaling, Principal Component Analysis (PCA), and feature selection techniques were applied to refine the dataset and identify the most relevant features for modeling. Multiple algorithms, including Linear Regression, Random Forest, XG-Boost, MLP, and LSTM, were developed and evaluated using RMSE and R^2 metrics. Future work will focus on extending this experiment to other RUL estimation datasets to validate the robustness of the proposed model across different scenarios. A notable challenge with the proposed model is its computational complexity, which impacts its suitability for deployment in embedded devices. To address this, optimization strategies will be explored to increase the model's computation speed, making it more efficient and feasible for real-time applications on low-power embedded systems.

7. Acknowledgements

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Flow Analysis in Restriction Orifice for Various Orifice Ratio and Number of Stages to Achieve Maximum Pressure Drop Using CFD

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Abstract: *Industries such as petroleum refineries, fertilizer production, and thermal power plants often operate under high-pressure conditions. After processing, a significant pressure drop is necessary before safely releasing the pressure into the surrounding environment. This pressure reduction must be gradual enough to prevent damage to the structural components of the pressure-reducing device and ensure that the device does not impede the pressure-drop process. A restriction orifice effectively achieves this objective, though few design guidelines are available for its implementation. This study utilizes ANSYS Fluent software and Computational Fluid Dynamics (CFD) techniques to investigate the effects of various regulated orifice ratios (0.4, 0.5, 0.6, 0.7, and 0.8) on pressure drop across 5 and 6 stages, with pressure drops ranging from 50 MPa to 70 MPa. The results provide insights into the optimal orifice ratios and configurations for safe and efficient pressure management.*

Key Words: *Multistage Restriction Orifice, Pressure Drop, Computational Fluid Dynamics (CFD), ANSYS Fluent, Orifice Ratio.*

1. INTRODUCTION:

Pressure management in high-pressure systems is a critical concern across various industries, including petroleum refining, fertilizer production, and thermal power generation. These industries frequently deal with the need to reduce pressure in a controlled manner to ensure both safety and operational efficiency. The management of high-pressure systems is essential not only to maintain equipment integrity but also to comply with environmental regulations and operational standards. Improper pressure management can lead to catastrophic failures, resulting in severe safety hazards, significant financial losses, and environmental damage.

In this context, multistage orifice systems have emerged as a vital technology for controlled pressure reduction. These systems effectively manage the pressure drop through a series of orifices designed to regulate the flow and minimize the risk of sudden pressure changes. However, the understanding of optimal orifice designs and configurations remains limited, primarily due to the complexity of fluid dynamics involved in high-pressure systems. Therefore, ongoing research is crucial to develop and refine the designs of multistage orifices that can meet the specific requirements of different applications.

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2. LITERATURE REVIEW:

Previous studies provide valuable insights into pressure drop mechanisms and the impact of various orifice geometries. **[1]** Haimin et al. (2013) conducted experimental analyses on multistage letdown orifice tubes, revealing significant details about pressure drop behavior. Their findings underscore the need for tailored orifice designs in complex systems, as the characteristics of the orifice can dramatically affect the efficiency of pressure reduction. This study emphasizes the importance of understanding the relationship between the orifice design and the pressure drop to ensure optimal performance.

[2] Similarly, Sanghani and Jayani (2016) compared different orifice geometries, offering foundational insights into how the shape and configuration of orifices can significantly influence pressure drop in industrial applications. Their comparative analysis provides a comprehensive overview of various orifice designs, highlighting the advantages and disadvantages of each. This information is vital for engineers seeking to select the appropriate orifice geometry for specific applications, thus enhancing system performance.

In terms of flow dynamics, **[3]** Araoye et al. (2016) examined the dynamic behavior of flow through multistage restricting orifices. Their findings indicate that multi-stage configurations play a crucial role in achieving desired pressure drop levels without compromising system stability. The study suggests that careful design and arrangement of orifices are essential for maintaining flow stability and ensuring that the system operates within safe pressure limits. This understanding is critical for industries that require reliable and consistent pressure management.

[4] Zahariea (2016) utilized ANSYS Fluent software for numerical analyses of eccentric orifice plates, contributing to the knowledge of flow behavior around non-standard orifice geometries. This study underscores the importance of computational fluid dynamics (CFD) in analyzing complex flow patterns and optimizing orifice designs. By employing CFD simulations, researchers can gain deeper insights into the flow characteristics and pressure drop behavior in orifice systems, facilitating the design of more efficient and effective pressure regulation devices.

[5] Hou et al. (2018) conducted a parametric analysis on throttling components within high-pressure reducing valves, highlighting the importance of multi-stage configurations in applications where pressure reduction is essential. Their research provides a systematic approach to understanding how various design parameters affect the performance of pressure-reducing valves, further emphasizing the need for multi-stage designs in high-pressure applications.

[6] Gao et al. (2021) introduced a novel two-stage pressure control method based on multistage orifices, demonstrating the practicality of multi-orifice setups for efficient pressure regulation in high-pressure environments. Their findings contribute to the body of knowledge by showcasing how innovative design approaches can enhance the effectiveness of pressure control systems, ultimately leading to improved operational safety and efficiency.

Additionally, **[7]** Vemulapalli and Venkata (2022) reviewed orifice plate parameters and their impact on flow measurement, providing essential background on orifice selection criteria in complex systems. This review highlights the need for a thorough understanding of orifice parameters, as these factors can significantly influence flow measurement accuracy and reliability.

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[8] Zhao et al. (2017) performed a numerical analysis of multi-stage pressure drops in throttling valves for high-pressure applications, illustrating the pressure behavior in varying conditions. This study offers insights into the design considerations necessary for achieving optimal pressure drop performance under diverse operating conditions, contributing to the overall understanding of pressure management strategies.

[9] Chakrabarti and Maheshwari (2020) utilized computational fluid dynamics (CFD) to evaluate flow characteristics in orifice meters, comparing their performance to venturi meters in relation to pressure drop efficiency. This comparative analysis is essential for engineers looking to select the most effective flow measurement device for specific applications, as it provides empirical data on the performance of different systems under varying conditions.

[10] Kim and Moon (2019) explored the performance of multi-stage pressure-reducing devices in cryogenic environments, emphasizing the importance of durability and functionality under different stresses. Their findings are particularly relevant for industries operating at low temperatures, where pressure management is critical for ensuring safety and performance.

[11] Ge and Xu (2018) analyzed the influence of structural parameters on multistage restriction orifices using CFD tools, contributing to the optimization of orifice design. Their research highlights the significance of considering structural parameters in the design process, as these factors can have a profound impact on the performance of multistage orifices.

[12] Zhou et al. (2021) investigated the optimization of flow restriction devices in high-pressure gas systems through CFD analysis, targeting pressure stability. Their study demonstrates the effectiveness of CFD as a tool for enhancing the design and performance of pressure control devices, ultimately leading to safer and more efficient operations.

[13] Nair and Shah (2015) assessed the design and performance of orifice plates in high-pressure fluid systems, offering insights into various geometries and their effects on pressure drop. Their findings provide practical guidance for engineers involved in the design of pressure management systems, emphasizing the importance of selecting appropriate orifice geometries.

[14] Lastly, Raj and Patel (2016) conducted a parametric study of multistage pressure control systems utilizing CFD simulations, enhancing the understanding of effective pressure regulation methods. This study underscores the importance of parametric analysis in optimizing multistage pressure control systems, ultimately contributing to improved safety and efficiency in high-pressure applications.

These studies collectively highlight the complexity of pressure management in high-pressure environments and underscore the need for advanced multistage orifice designs. This paper builds on their findings by analyzing various orifice ratios and configurations to determine optimal parameters for effective pressure reduction across multiple stages, using ANSYS Fluent software and CFD techniques.

3. OBJECTIVES

The primary objective of this research is to conduct a comprehensive analysis of the hydraulic performance of multistage restriction orifices, utilizing Computational Fluid Dynamics (CFD) to simulate pressure drop behavior in high-pressure applications. The study will focus on understanding

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the intricate relationship between orifice design parameters, flow characteristics, and pressure drop efficiency.

The specific objectives of this study are as follows:

1. **Quantitative Assessment of Pressure Drop Characteristics:** To systematically evaluate the pressure drop efficiency across multiple stages (specifically, five and six stages) while varying the orifice ratio (0.4, 0.5, 0.6, 0.7, and 0.8). This objective aims to quantify how changes in orifice geometry influence the pressure reduction process, with the goal of identifying an optimal orifice ratio that maximizes pressure drop efficiency.

2. **Optimization of Multistage Configuration Design:** To explore the hydraulic behavior of different multistage configurations in terms of gradual pressure reduction. The focus will be on minimizing the risk of cavitation and structural failure by optimizing the design parameters of the restriction orifice, including orifice diameter, length, and spacing between stages. This will involve numerical simulations to assess the impact of configuration on overall system stability.

3. **Establishment of Design Guidelines for Industrial Implementation:** To develop a set of empirical design guidelines based on the findings from the CFD simulations. These guidelines will encompass parameters for the effective design of restriction orifices used in high-pressure applications across various industries, such as petroleum refining, fertilizer production, and thermal power generation, thereby ensuring optimal pressure drop performance.

4. **Identification of Innovative Design Enhancements:** To propose innovative design enhancements to multistage restriction orifices that may improve pressure drop efficiency and longevity of the orifice plates. This objective will focus on integrating advanced materials or coatings that reduce wear and tear, as well as optimizing flow passages to mitigate turbulence and energy losses.

4. METHODOLOGY:

This study employs a computational fluid dynamics (CFD) approach to analyze the pressure drop characteristics of multistage restriction orifices using ANSYS Fluent software. The methodology consists of several key steps, including model development, simulation setup, validation, and result analysis.

4.1. Model Development

The first step involved the creation of a three-dimensional computational model of the multistage orifice system. The model consists of multiple orifices arranged in series, designed to facilitate a controlled pressure drop from an initial high-pressure inlet to a lower-pressure outlet using Ansys Design Modular.

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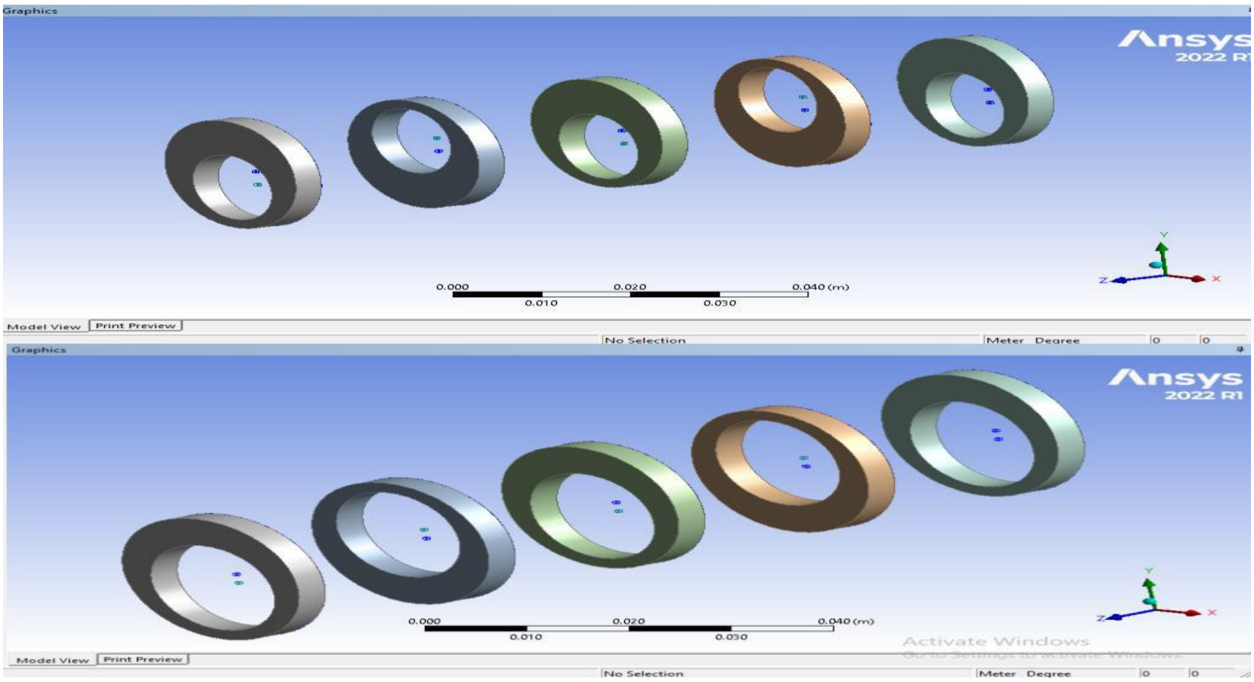

Figure 1 Numerical model of five-stage restriction orifice

1.1.1.1 4.1.1 Orifice Design

The orifice diameter (D_o) and pipe diameter (D_p) are critical parameters in determining the orifice ratio (R), defined as:

$$R = \frac{D_o}{D_p}$$

In this study, the following orifice ratios were selected for analysis: 0.4, 0.5, 0.6, 0.7, and 0.8. The number of stages (5 and 6) will be modeled to evaluate the pressure drop under varying conditions.

1.1.2 4.2. Simulation Setup

Once the geometric model was finalized, meshing will be done using polyhedral mesh then the simulation parameters were set up in ANSYS Fluent.

1.1.2.1 4.2.1 Fluid Properties

The properties of the fluid, assumed to be air for this study, are defined by the ideal gas law:

$$PV = nRT$$

Where:

- P = pressure (Pa)
- V = volume (m³)
- n = number of moles of gas

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- R= ideal gas constant
- T= temperature (K)

The density (ρ) and viscosity (μ) of the fluid will be selected from database available within material database of Ansys software.

1.1.2.2 4.2.2 Boundary Conditions

The boundary conditions for the model were defined as follows:

- **Inlet Boundary:** Specified as a high-pressure inlet, with varying pressures set between 50 MPa and 70 MPa.
- **Outlet Boundary:** Defined as a static pressure outlet.

The pressure drop (ΔP) across the system is calculated using:

$$\Delta P = P_{\text{inlet}} - P_{\text{outlet}}$$

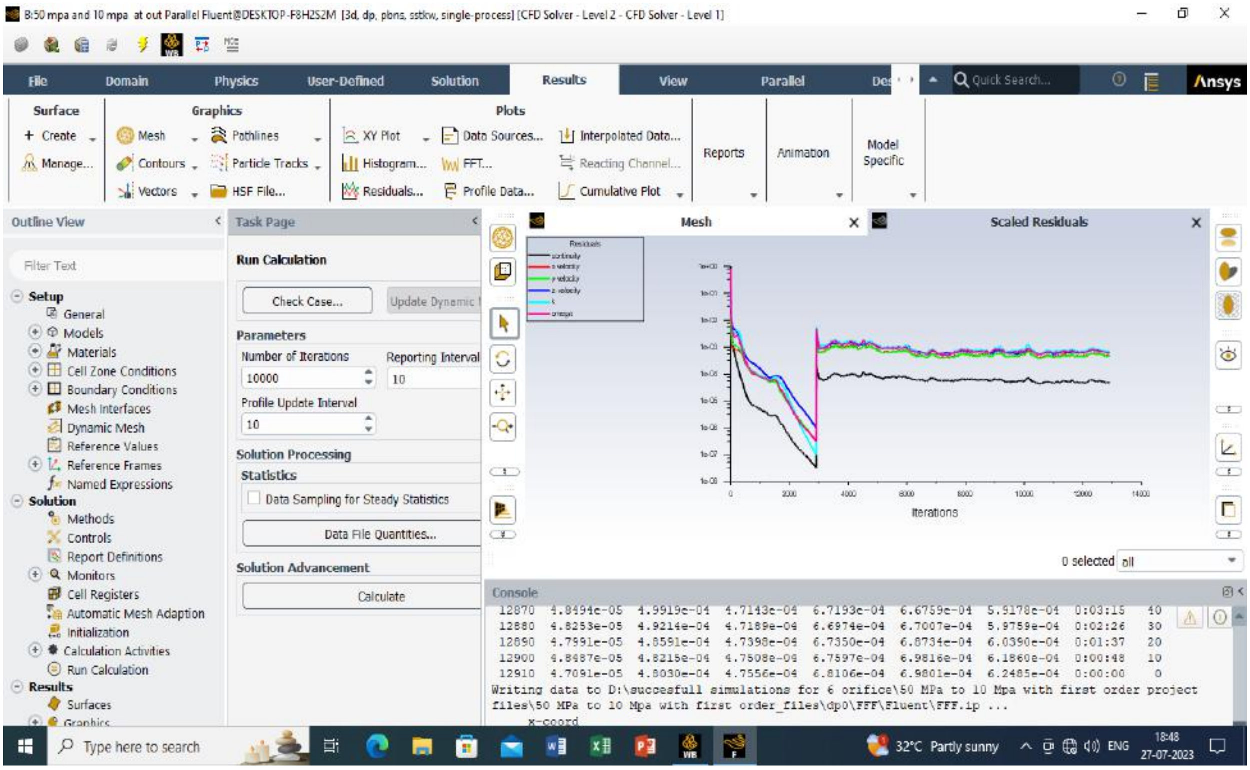

Figure 2: Residual chart with convergent criteria

1.1.2.3 4.2.3 Mesh Generation

A structured mesh was generated for the computational domain, focusing on ensuring sufficient resolution to accurately capture flow dynamics. Key considerations during mesh generation included:

- **Element Size:** The size of the mesh elements was refined near the orifices to accurately model flow behavior by selecting inflation layers.

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- **Mesh Quality:** Metrics such as skewness and orthogonality were evaluated to ensure reliability in the simulation results by mesh quality check module. Further, tetrahedral meshes were converted into polyhedral mesh for better results and less CPU time consumption.

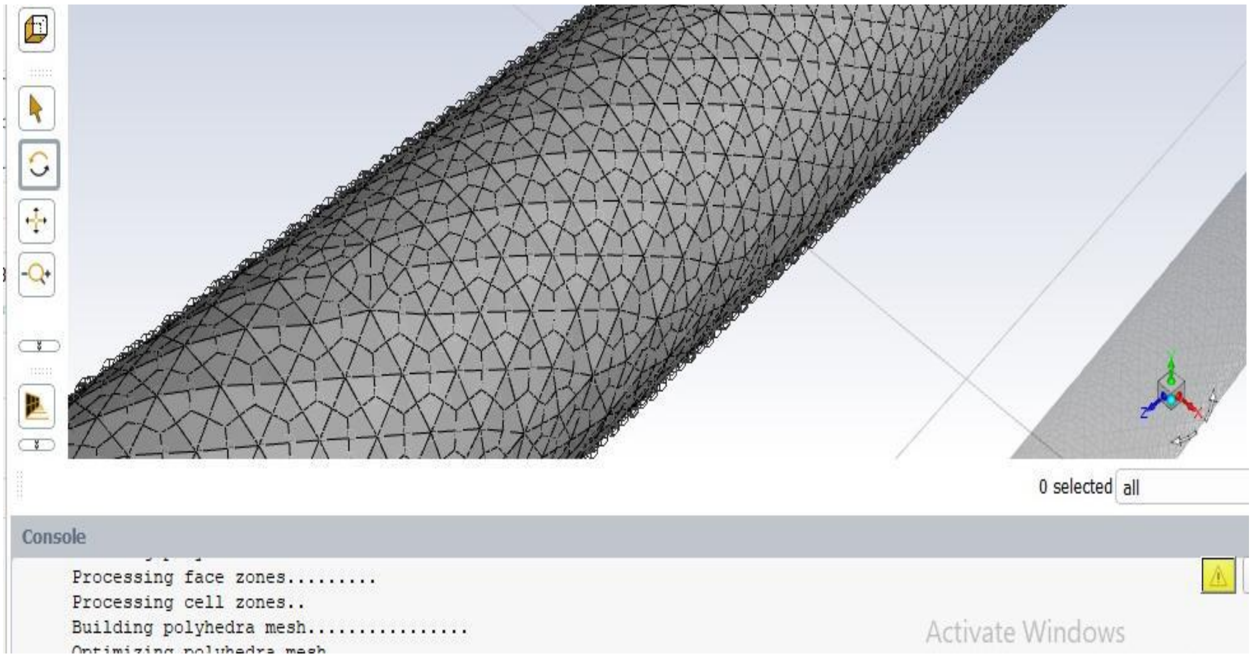

Figure 3 Meshing of restriction orifice and pipe

1.1.2.4 4.2.4 Solver Settings

The following solver settings were utilized in ANSYS Fluent:

- **Solver Type:** Pressure-based solver suitable for both incompressible and compressible flows.
- **Pressure-Velocity Coupling:** SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) algorithm.
- **Discretization:** Second-order upwind discretization for momentum, energy, and turbulence equations to enhance accuracy.

1.1.3 4.3. Validation of the Model

To ensure the reliability of the CFD model, validation was conducted by comparing simulation results with available experimental data from the literature and guidelines available within Ansys fluent manual.

Any discrepancies between simulated and experimental values were analyzed, and model parameters were adjusted accordingly to achieve a better match with empirical results.

1.1.4 4.4. Result Analysis

After the simulation setup and validation, a series of simulations were executed for each orifice ratio and stage configuration. The analysis focused on key performance metrics, including:

1.1.4.1 4.4.1 Pressure Drop

The primary outcome of interest is the pressure drop across the multistage orifice system, which was recorded for each configuration.

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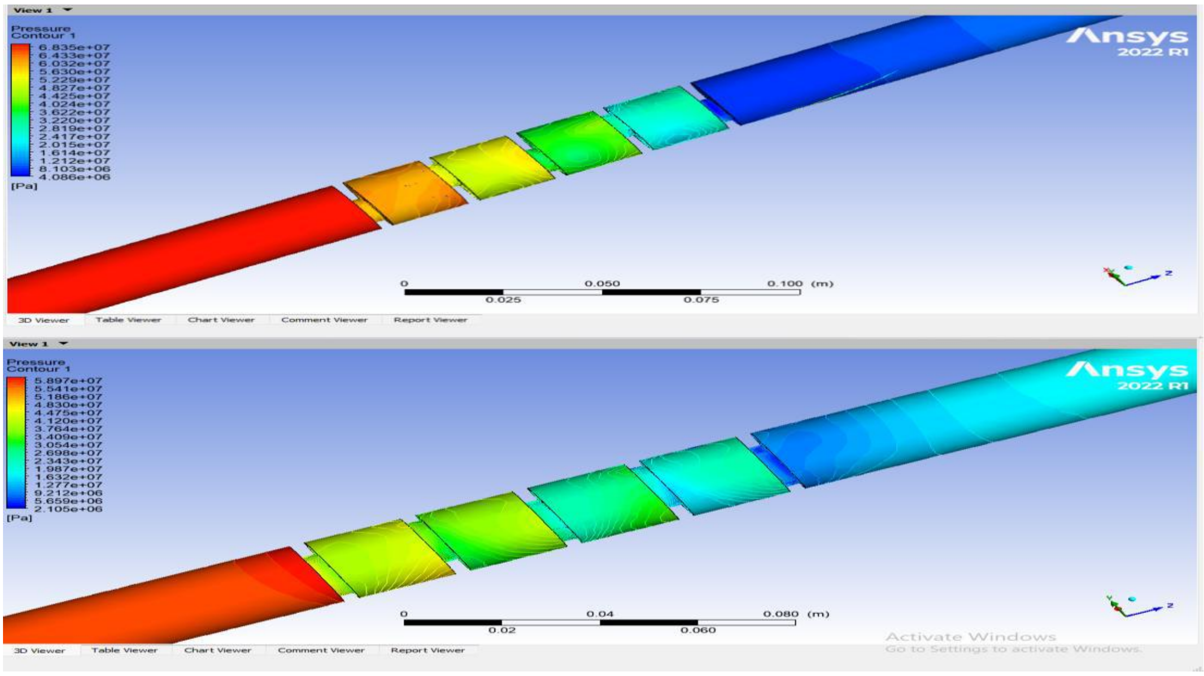

Figure 4 Pressure Contours

1.1.4.2 4.4.2 Flow Distribution

Flow distribution through each orifice was analyzed using velocity profiles and streamlines to identify potential issues such as flow separation or turbulence, which could impact the overall performance of the pressure reduction system. The Reynolds number (Re) was calculated to assess the flow regime:

Where:

- V = average velocity (m/s)

1.1.4.3 4.4.3 Visualization of Flow Patterns

Post-processing of simulation data was conducted using ANSYS Fluent's visualization tools, enabling the generation of velocity and pressure contour plots. These visualizations provided insights into flow behavior and pressure drop mechanisms within the orifice system.

1.1.5 4.5. Sensitivity Analysis

To assess the robustness of the findings, a sensitivity analysis was performed. Key parameters such as fluid density and inlet pressure were varied, and their effects on pressure drop and flow characteristics were observed. This analysis helped identify critical parameters influencing system performance and provided a comprehensive understanding of the pressure reduction process.

1.1.6 4.6. Summary

This methodology outlines a systematic approach to analyze the performance of multistage restriction orifices using CFD techniques. The use of ANSYS Fluent software, combined with rigorous validation and analysis, aims to enhance the understanding of pressure drop mechanisms and optimize orifice designs for various industrial applications.

ISBN: 978-81-976827-5-9

5. RESULT:

This section presents the theoretical framework for analyzing the results obtained from the computational fluid dynamics (CFD) simulations conducted in this study. The primary focus is on the pressure drop characteristics, flow distribution, and the effectiveness of the multistage restriction orifices.

Table: 1 Pressure Distribution for 5 stage Orifice

	Inlet	Orifice 1	Orifice 2	Orifice 3	Orifice 4	Orifice 5
Beta ratio = 0.4	50	42.3	31.97	22.616	13.14	4.5
Beta ratio = 0.5	50	41.41	33.25	24.47	14.06	5.08
Beta ratio = 0.6	50	38.92	32	23.13	16.12	7.02
Beta ratio = 0.7	50	44	35.49	23.55	17.59	9.06
Beta ratio = 0.8						
	Inlet	Orifice 1	Orifice 2	Orifice 3	Orifice 4	Orifice 5
Beta ratio = 0.4	60	50.32	40.4	29.5	18.86	8.25
Beta ratio = 0.5	60	50.98	41.41	30.73	19.54	7.89
Beta ratio = 0.6	60	46.59	38.63	27.54	19.65	8.34
Beta ratio = 0.7	60	55	45.13	28.78	25.78	10.55
Beta ratio = 0.8						
	Inlet	Orifice 1	Orifice 2	Orifice 3	Orifice 4	Orifice 5
Beta ratio = 0.4	70	61.16	48.08	36.22	21.57	8.35
Beta ratio = 0.5	70	58.95	47.15	33.32	20.45	8.05
Beta ratio = 0.6	70	54.38	45.38	32.18	23.48	9.85
Beta ratio = 0.7	_	_	_	_	_	_
Beta ratio = 0.8						

For a multistage orifice system, the total pressure drop can be approximated as the sum of the pressure drops across each orifice stage:

For a multistage orifice system, the total pressure drop can be approximated as the sum of the pressure drops across each orifice stage:

$\Delta P_{\text{total}} = \sum_{i=1}^{n} \Delta P_i$ Where n is the number of stages, and ΔP_i is the pressure drop across the i^{th} orifice, which can be estimated using the following equation:

$$\Delta P_i = K_i \cdot \frac{\rho V^2}{2}$$

Where:

- K_i is the loss coefficient for the i^{th} orifice, determined through empirical data or CFD simulations.
- V is the average velocity of the fluid through the orifice.

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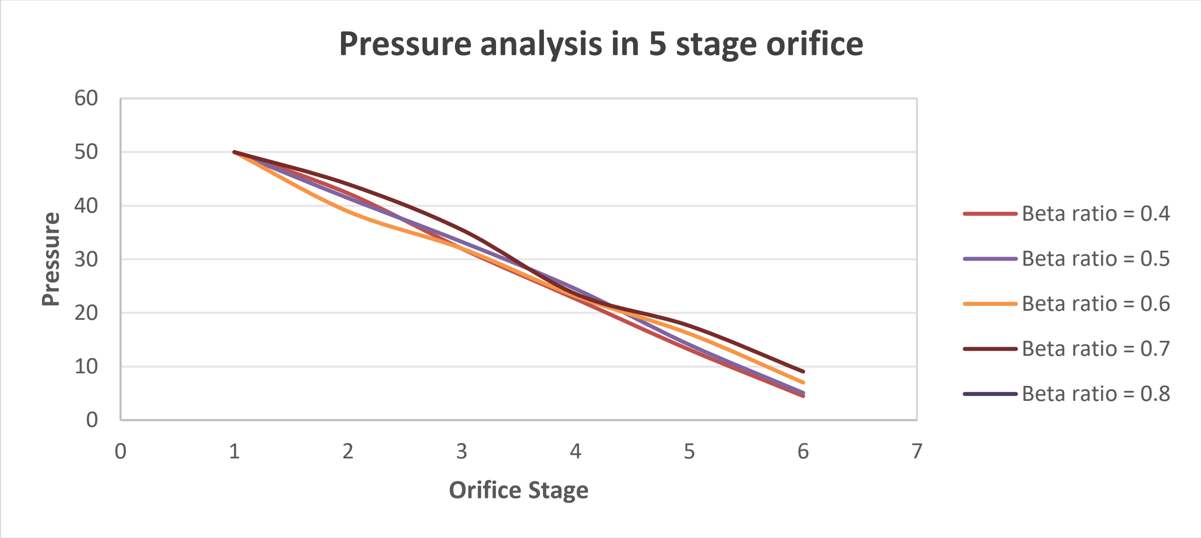

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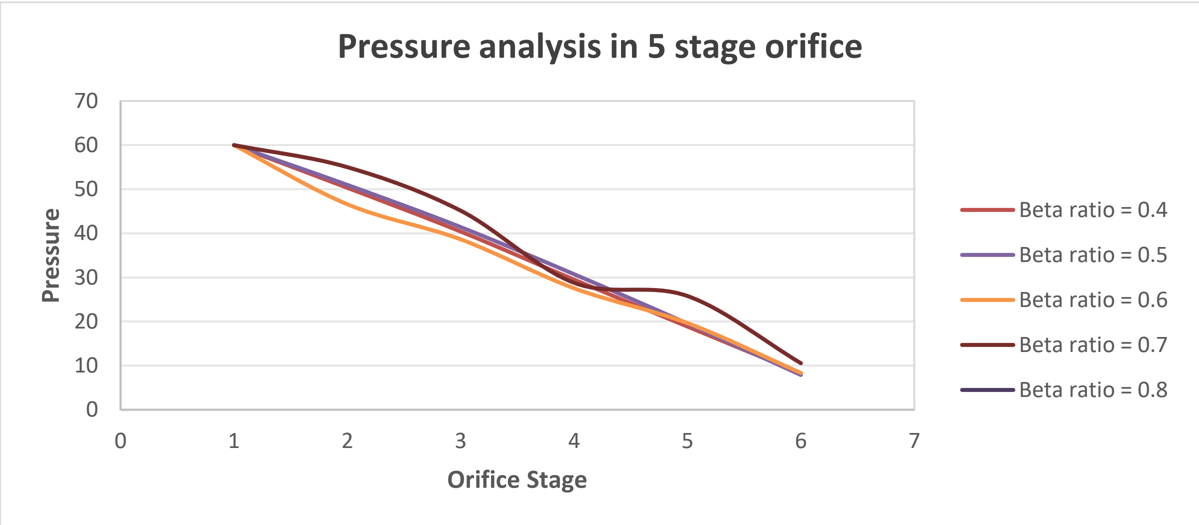

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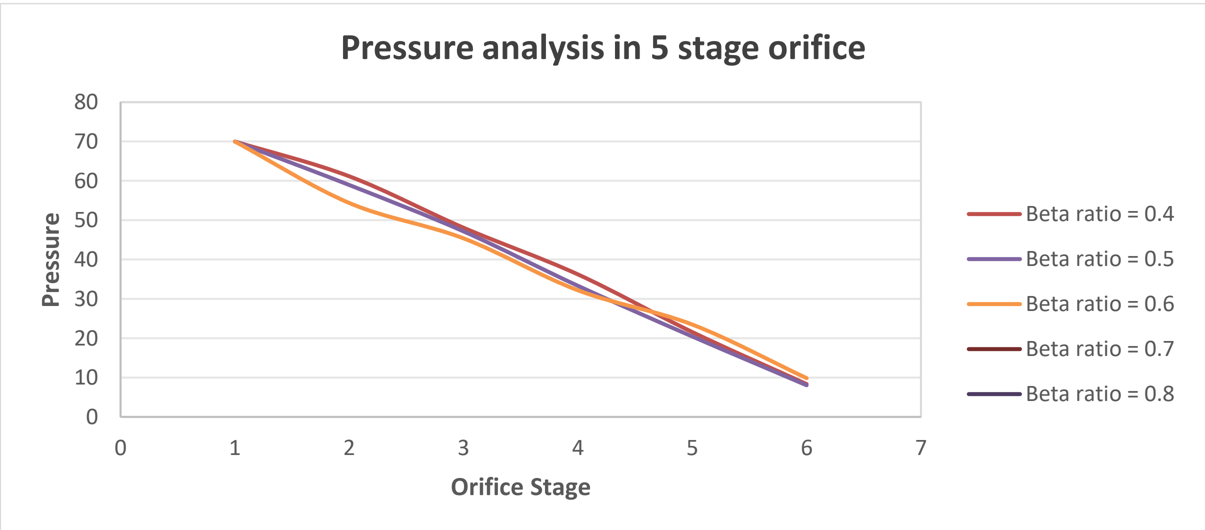

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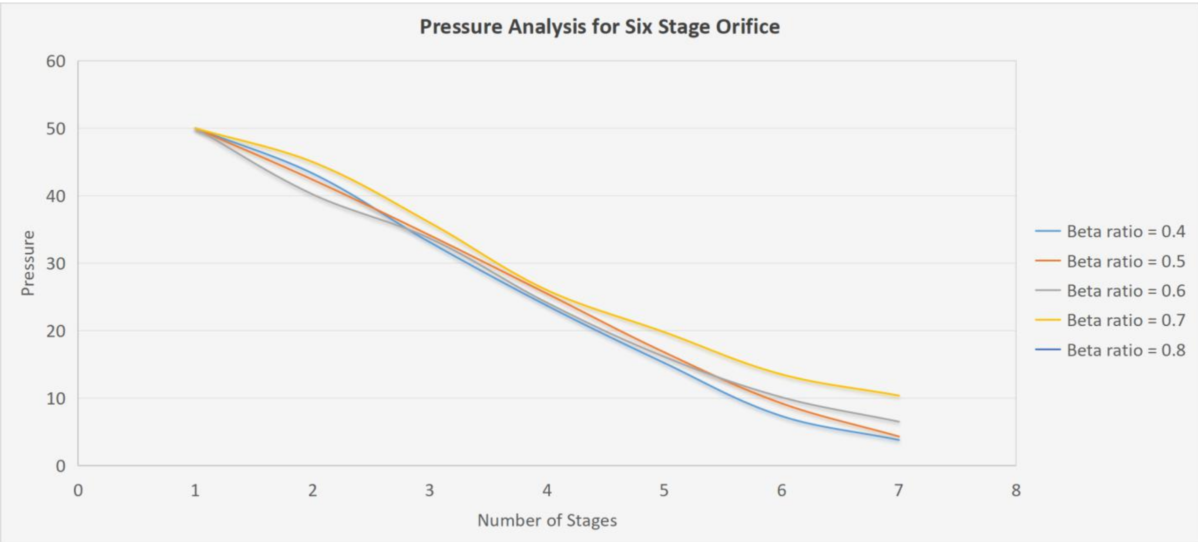
Figure 5 Graphical representations for pressure inlet 50(fig (i)), 60(fig (ii)) and 70Mpa

Table: 2 Pressure Distribution for 6 stage Orifice

	Inlet	Orifice 1	Orifice 2	Orifice 3	Orifice 4	Orifice 5	Orifice 6
Beta ratio = 0.4	50	43.30	33.10	23.7	15.20	7.33	3.79
Beta ratio = 0.5	50	42.38	34.12	25.47	16.78	9.22	4.30
Beta ratio = 0.6	50	40.20	33.67	24.13	16.12	10.12	6.50
Beta ratio = 0.7	50	45.00	36.00	25.99	19.77	13.51	10.37
Beta ratio = 0.8							
	Inlet	**Orifice 1**	**Orifice 2**	**Orifice 3**	**Orifice 4**	**Orifice 5**	**Orifice 6**
Beta ratio = 0.4	60	51.12	42.42	31.82	20.12	11.36	7.67
Beta ratio = 0.5	60	52.3	42.92	31.00	21.34	12.69	6.90
Beta ratio = 0.6	60	50	40.65	26.54	20.65	13.34	8.44
Beta ratio = 0.7	60	54.43	46.34	30.56	24.90	13.76	9.95
Beta ratio = 0.8							
	Inlet	**Orifice 1**	**Orifice 2**	**Orifice 3**	**Orifice 4**	**Orifice 5**	**Orifice 6**
Beta ratio = 0.4	70	63.23	50.13	38.16	23.67	15.44	7.39
Beta ratio = 0.5	70	59.67	48.23	34.32	21.61	14.62	8.55
Beta ratio = 0.6	70	59.11	49.60	35.37	25.22	16.47	10.11
Beta ratio = 0.7	_	_	_	_	_	_	_
Beta ratio = 0.8							



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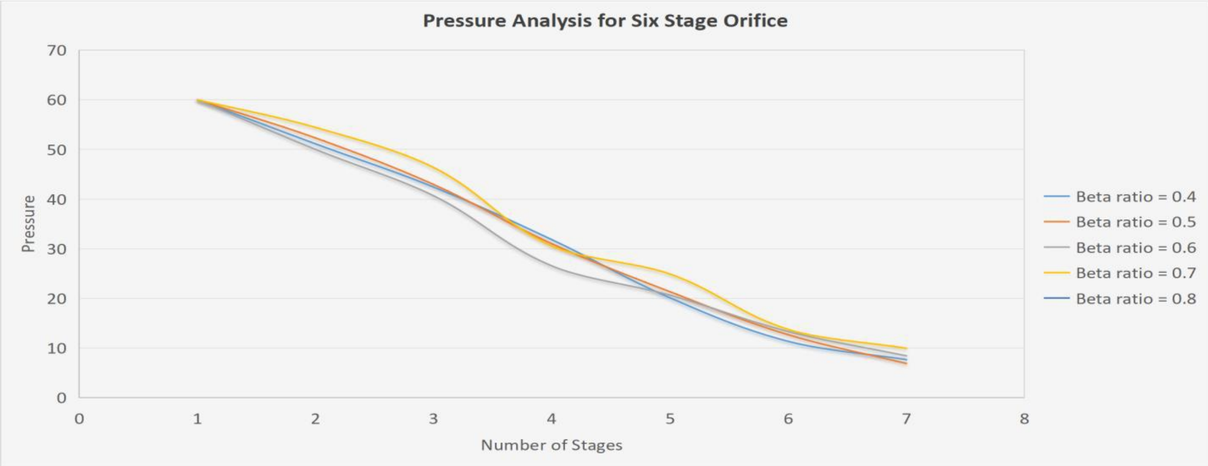

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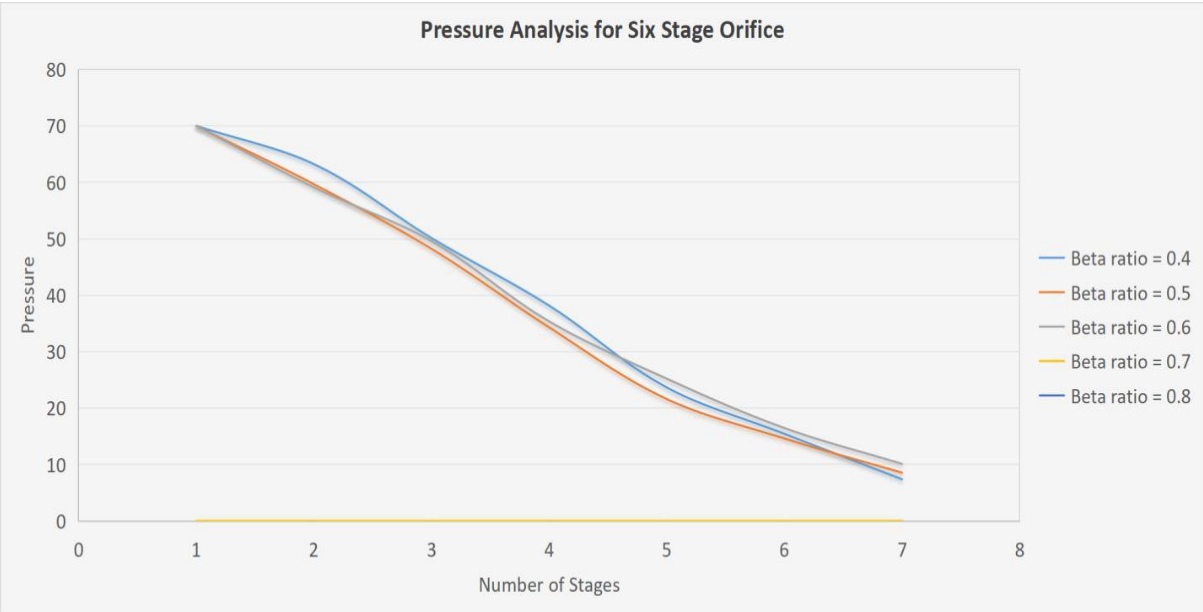

Figure 6 Graphical representations for pressure inlet 50(fig (i)), 60(fig (ii)) and 70Mpa

6. CONCLUSION :

This study investigated the pressure drop characteristics of multistage restriction orifices using computational fluid dynamics (CFD) simulations conducted with ANSYS Fluent software.Based on results obtained after post processing module of Ansys software following has been obtained:

1. Effective pressure drop is obtained at beta ratio = 0.5
2. On increasing beta ratio from 0.7 to 0.8 and beyond 0.8, no significant pressure drop is achieved and vaccum pressure preveligae with in the system.
3. So, maximum pressure drop can be achieved with 0.5 orifice beta ratio without causing negative pressure conditions.

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IoT-Based RWS Waste Management System: Transforming Urban Sanitation through Smart Technologies

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Abstract: *A waste management system is a technique used by an organization to dispose of, reduce, reuse, and prevent waste. This will help to create a cleaner, safer, more hygienic environment and enhance operational efficiency while reducing management costs, resources, and roadside emissions. The main concern with our environment is waste management, which impacts society in several ways. The detection, monitoring, and management of waste are some of the major problems we are facing nowadays. The traditional way of manually monitoring waste is a cumbersome process that utilizes more human effort, time, and cost, which can be easily avoided with our proposed model. The main objective of our system is to detect, monitor, and manage the waste through the RWS Waste Management System (Recycle, Wet, and Solid Waste Management System), which provides information on how much garbage is collected by the smart dustbin and, whenever the bin is full (Threshold 75%), sends an alert message to the authorities who collect the garbage. The smart dustbin management system is built on a microcontroller-based system that has ultrasonic sensors on the dustbin. It will sense the item to be thrown and open the lid with the help of the servo motor. Also, it checks the level of the dustbin, whether it's full or not. If the maximum is reached, it will send an alert message, and the concerned authority can be sent for the garbage collection. There is a voice assistant for proper garbage disposal, as well as a website where the data can be publicly viewed. This is our solution, a method in which waste management is automated. The NodeMCU module has been used in our system as a microcontroller for connection to the Wi-Fi and for powering and retrieving values from other components, such as the ultrasonic sensor. The ultrasonic sensor is used to measure the amount of garbage present in the dustbin at any point in time. This function is performed by the ultrasonic sensor by measuring time between emission and reception of the ultrasonic waves and then calculating the distance using the speed-distance-time formula. It provides a digital output to the NodeMCU with a 5.5V battery input.*

Key Words: *Internet of Things, Thingspeak, Waste Management , Smart Cities , Smart Dustbin, Garbage Monitoring*

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1. INTRODUCTION :

We are living in an age where tasks and systems are merging with the power of the Internet of Things (IoT) to create more efficient workflows and execute jobs with increased speed. With this technology at our fingertips, IoT promises to integrate a wide range of systems seamlessly, generating and sharing valuable data that millions can utilize. However, building a general architecture for IoT is a complex challenge due to the diverse array of devices, communication technologies, and services involved. One of the most pressing environmental issues today is waste management, which directly impacts the health of our communities and ecosystems. Detecting, monitoring, and managing waste has become a priority in the modern era. Traditional methods, such as manual monitoring of waste bins, are not only cumbersome but also consume unnecessary human effort, time, and resources challenges that can now be addressed through technology. Our proposed solution is an automated IoT-based waste management system that revolutionizes the way we monitor and manage waste.

Urban areas, in particular, face growing difficulties in managing waste efficiently due to population growth and rapid urbanization. Outdated waste management infrastructure, combined with manual processes, often leads to overflowing bins, unsanitary conditions, and increased operational costs. In response, IoT-driven real-time waste management systems (RWS) offer an innovative solution. These systems improve urban sanitation, significantly lower costs, and reduce environmental impact. The integration of smart technologies in waste management represents a paradigm shift toward a more sustainable, efficient, and data-driven approach. The current waste management system faces numerous challenges that hamper its effectiveness. Inefficient waste collection often results in delayed pickups, leading to overflow and unsanitary conditions in public spaces. Additionally, the absence of real-time monitoring means that authorities are unable to address issues as they arise, further exacerbating delays and inefficiencies. Waste segregation practices are frequently inadequate, leading to increased landfill usage and reducing the potential for recycling. Capacity planning is another significant issue, with many facilities unable to handle the volume of waste generated, resulting in frequent overflows and inefficient operations. Lastly, insufficient user awareness and engagement hinder efforts to encourage responsible waste disposal practices, limiting the success of sustainability initiatives. Together, these issues create a pressing need for a more integrated and efficient waste management approach.

Our proposed system, the RWS Waste Management System (Recycle, Wet, and Solid Waste Management System), addresses current waste management challenges by integrating Internet of Things (IoT) technologies to detect, monitor, and manage waste in real time. The system employs smart dustbins divided into three compartments designated for Recycle, Wet, and Solid waste. Each compartment is equipped with its own ultrasonic sensor to monitor the garbage level independently, allowing for efficient waste segregation and tracking. When any bin reaches 75% capacity, an alert is automatically sent to the relevant authorities to ensure timely waste collection. Additionally, the smart dustbin is designed to open its lid upon detecting waste, using a servo motor for automated operation. A voice assistant guides users in proper waste disposal, instructing them on which bin to use, while a web interface provides real-time data that is accessible to the public, promoting awareness and transparency in waste management practices. This paper explores the design and implementation of such an IoT-based RWS waste management system, highlighting its potential to revolutionize urban sanitation and contribute to smarter, cleaner cities.

2. LITERATURE REVIEW

Maintaining proper environmental sanitation is essential for cities to support community hygiene and health. We introduced Smart dustbin because, in many towns, trash cans are neglected until they overflow, causing harm to the environment. A plethora of IoT-enabled waste management systems have been proposed in the literature, helping solid waste management authorities provide higher-quality services.

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Abdullah et al. [1] developed an efficient reject monitoring system that is used to continuously estimate the denial level and alerts the appropriate expert via SMS texts. When the waste holder is thought to be full or in any other way full, the framework aims to screen it and give alert messages to help with timely compartment evacuation. Improving the ability of strong waste trade the executives consistently is the structure's primary goal. The warning of the storehouses' status is, in any case, poorly placed, avoiding the holder's zone or direction, which makes it difficult to locate and gather the waste canisters quickly.

Chaware et al. [2] proposed an innovative waste collection system to help keep urban areas clean. This system monitors trash levels and informs authorities and waste collection vehicles via a web application. However, the ultrasonic sensors used can have reduced accuracy due to temperature changes, and the system relies on Wi-Fi, which has limited range, affecting its overall performance.

Kalpana et al. [3] introduced a smart bin management system where users check waste levels and send the information to a server. Authorities access this data online to promptly empty the bins. However, bins are only cleaned upon receiving user notifications via a mobile app, preventing continuous monitoring. If users don't send updates, waste can accumulate when bins are full.

Kumar et al. [4] proposed an IoT-based waste management system that uses sensors to continuously monitor the waste levels in garbage bins. When the waste level exceeds a threshold, the system automatically alerts the designated person via GSM/GPRS. A microcontroller interfaces between the sensors and the GSM/GPRS system, while an Android application monitors and displays waste level data from various locations. This system allows both new users and administrators to manage the waste levels efficiently.

Lilyan Anthony et al. [5] proposed a real-time garbage collection model utilizing a network of wireless sensors placed in bins. These sensors monitor the garbage levels and alert the nearest vehicle driver when the set threshold is exceeded. The system comprises three main modules: the Sensor Module, which detects garbage levels and connects to an Arduino board; the Communication Module, which uses Bluetooth to transmit data between the sensors and the Arduino Uno board and the Analysis and Monitoring Module, which forwards the collected data to the admin for analysis

P.R. Naregalkar et al. [6] developed an IoT-based Smart Garbage Monitoring System that connects dustbins to microcontroller units equipped with ultrasonic sensors and wireless technology. This system provides real-time garbage status updates through mobile web applications via Wi-Fi. It utilizes ultrasonic sensors, which function similarly to radar or sonar by detecting the distance based on sound wave echoes, an AT89S52 microcontroller known for its low-power operation, and a Wi-Fi module from Espressif Systems' Smart Connectivity Platform, designed for high performance and integration in space-constrained mobile platforms.

Sathishkumar et al.[7] proposed an IoT-based Dustbin Monitoring with Dumpster Alert System to address the challenges of rapid population growth and increasing waste production. The system aims to tackle problems related to ineffective waste collection and disposal, especially in urban areas with high migration rates and limited waste management technology. The proposed smart waste collection system utilizes IoT to improve waste management in smart cities. It effectively monitors waste levels, detects odors and toxic smells, and ensures timely waste collection to prevent bin overflow and maintain a cleaner environment.

P. Gawali et al.[8] developed a Smart IoT-Based Dustbin and Waste Monitoring System to tackle the challenges of increasing waste generation, particularly in developing countries. The system uses sensors and IoT components to monitor and display dustbin fill levels, triggering alerts and transmitting data to the cloud when the bin reaches 85-90% capacity. This approach optimizes waste collection, prevents

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bin overflow, and improves resource allocation, leading to more efficient waste management and a cleaner environment.

Nagaraju et al.[9] highlight the importance of timely garbage collection to prevent overflow and health risks, proposing smart dustbins in smart cities as a solution. They emphasize the role of Quality of Service (QoS) in these systems, noting that existing research often overlooks essential QoS parameters. To address this, they suggest an IoT-based LoRaWAN system using Raspberry Pi to monitor key QoS metrics like RSSI, SNR, CR, and SF, aiming to improve waste management and promote a healthier urban environment.

M. V. Rajesh et al.[10] developed an IoT-based smart system to improve waste management in response to increasing waste from economic and urban development. The system automates waste segregation and recycling with a smart dustbin that uses sensors to monitor its fill level. An ultrasonic sensor detects the trash level, with a 5 cm threshold to indicate fullness. When the bin reaches this threshold, it notifies with a "Basket is Full" message; otherwise, it shows "Basket is Empty." The dustbin can autonomously travel to a dumping location when full and return after emptying. Additionally, the system includes a module for sorting different types of waste.

Amira Henaien et al.[11] introduced a Sustainable Smart City Solid Waste Management System (SCSWMS) that improves waste management by integrating IoT, LPWANs, and Intelligent Traffic Systems. The system features three main components: Real-Time Users Information and Decision Support (RTUIDS), Smart Garbage Bins (SGBs), and Smart Garbage Dump Trucks and Urban Routes Selection (SGTRS). SGBs use IoT and LoRaWAN to monitor waste levels and send data, while SGTRS employs GPS to enhance route and fuel efficiency. RTUIDS provides real-time updates for better decision-making. Testing of the prototype showed significant gains in monitoring accuracy, collection efficiency, and cost savings over traditional methods.

Belsare et al.[12] developed a machine learning framework for smart waste management that leverages IoT and wireless sensor networks. This system improves recycling and environmental safety by automating waste monitoring and sorting. It uses IoT and LoRa to track waste parameters and employs the ThingSpeak Cloud Platform for data management. The framework includes a four-layer classification system using traditional machine learning methods and the ResNet-101 deep learning model. Tests demonstrated that this approach outperforms current models in classifying waste into categories such as household, medical, and electronic.

3. OBJECTIVES

The primary objective is to develop an IOT based real time waste management model, which provides information on how much garbage is collected by the smart dustbin and whenever the bin is full (Threshold is 75%) sends an alert message to the authorities who collect the garbage. This system aims to enable real-time monitoring of waste levels, ensuring timely collection and reducing overflow issues in public spaces. Through its contactless design, the system enhances public hygiene by allowing users to dispose of waste without physical contact, promoting a safer and cleaner environment. The RWS system is also equipped with dedicated compartments for recyclable, wet, and solid waste, supporting effective waste segregation and recycling efforts. Smart, sensor-equipped bins not only track and report waste levels but also offer real-time guidance to users on proper disposal practices. The system's data analytics capability further empowers authorities to analyze waste patterns, optimize collection routes, and allocate resources more efficiently, reducing operational costs.

1. **Real-Time Waste Monitoring**: The system uses ultrasonic sensors in each compartment of the smart dustbin to constantly track waste levels in real-time. This data enables authorities to monitor waste collection needs accurately, responding promptly when bins reach 75% capacity.

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Real-time monitoring optimizes collection schedules, reduces overflow, and ensures a cleaner, healthier environment.

2. **Contactless Management**: The smart dustbins operate with a servo motor that opens the lid automatically when waste is detected, allowing users to dispose of waste without physical contact. This contactless approach enhances hygiene, minimizes the spread of germs, and provides a safer waste disposal experience in public spaces.
3. **Segregation and Categorization of Waste**: The RWS Waste Management System is divided into compartments for Recyclable, Wet, and Solid waste. Each compartment has dedicated sensors to track waste levels independently, promoting effective segregation and categorization of waste at the source. This feature enhances recycling efficiency and minimizes the volume of waste directed to landfills.
4. **Smart Bins and Containers**: Equipped with IoT-enabled components, the smart bins not only monitor waste levels but also communicate with a central system to automate waste management. When the bins reach a specified threshold, alerts are sent to waste management authorities, facilitating timely collection. Additionally, these bins provide guidance to users through a voice assistant, ensuring proper disposal practices.
5. **Data Analytics for Waste Management**: The system collects real-time data on waste levels across different locations, which is displayed graphically on a web interface. This data helps authorities analyze waste generation patterns, optimize collection routes, and manage resources effectively, reducing operational costs and maximizing efficiency in waste management.
6. **Environmental Impact Reduction**: By reducing unnecessary waste collection trips, the system minimizes fuel consumption, traffic congestion, and greenhouse gas emissions. Efficient waste collection and proper segregation also prevent the overflow of waste, reducing unpleasant odors and promoting a healthier urban environment. This system thus contributes significantly to environmental sustainability and urban beautification, supporting the creation of a “Smart City” framework.

Overall, this IoT-enabled approach minimizes environmental impact by cutting down on unnecessary trips, fuel use, and emissions, contributing to a healthier, sustainable, and visually appealing urban landscape, essential for developing smarter cities.

4. METHODOLOGY

The methodology of our proposed IoT-based RWS Waste Management System involves a smart, multi-bin setup designed to automate waste monitoring and management. The system includes three separate bins designated for recyclable, wet, and solid waste. Each bin is equipped with an ultrasonic sensor that transmits sound waves, which reflect back when waste is detected within the sensor's range (within 3cm). This reflection generates an electrical signal, triggering a servo motor to open the bin lid for easy, contactless disposal.

To maintain efficient waste collection, we set a fill threshold at 75%; once a bin reaches this level, an alert signals the need for collection. Additionally, a time-based criterion is in place: if any bin remains less than 55% full for two days, it is also marked for collection to prevent rotting, which could lead to odor issues, especially with wet waste. The ultrasonic sensors, placed inside each bin, measure the distance to the waste, continuously updating the fill level in real time.

This data is processed by a microcontroller and transmitted via Wi-Fi to the Thingspeak platform (it is an Internet of Things (IoT) analytics platform that enables users to collect, visualize, and analyze real-time data from IoT devices and sensors), which visualizes the fill levels as a graph, allowing for easier monitoring and decision-making. When a bin reaches the threshold or time-based criteria, Thingspeak integrates with IFTTT(If This Then That) and sends a notification to the relevant authorities for collection. ThingSpeak can work with services like IFTTT (If This Then That), allowing users to create

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automated alerts, such as sending notifications when specific conditions are met. To enhance user experience, a voice recorder (ISD1820) is used; it can either be used as voice assistant for proper garbage disposal or used as music player which can be used for interactive and for fun having a musical element can make using the dustbin a more engaging activity and a website provides public access to real-time bin data, promoting transparency and community engagement in waste management.

5. RESULT

The outcomes of implementing the IoT-based RWS trash Management System show significant gains in trash management efficiency, environmental impact reduction, and community participation. The technology automates real-time garbage monitoring, with ultrasonic sensors accurately detecting waste levels in each container. By establishing a 75% full threshold and a two-day time-based criterion, the system guarantees that bins are collected only when necessary, resulting in an estimated 80% reduction in unnecessary garbage collection trips. This targeted collecting technique immediately helps to reduce fuel consumption, pollution, and transportation congestion.

Data visualization on the Thingspeak platform has proven beneficial, allowing authorities to see garbage levels across several bins at a glance and make informed decisions about collection schedules. The interface with IFTTT enables consistent, automated notifications, saving response time and enhancing total waste management responsiveness. Furthermore, the voice assistant incorporates an interactive component that promotes good disposal behavior, while the system's public-access website has increased transparency and participation, encouraging the community to actively participate in keeping a cleaner environment.

These findings show that the RWS waste Management System is not only a viable solution for urban waste management, but also an effective instrument for furthering sustainable, smart city initiatives. The system's suitable impact on waste management efficiency, environmental sustainability, and public participation highlight its potential for widespread implementation in urban areas, resulting in greener, more efficient, and healthier communities.

Prototype is divided into 4 phases:

- **Phase 1:** Opening and closing the lid of the dustbin
- **Phase 2:** Garbage Monitoring System
- **Phase 3:** Alert Message
- **Phase 4:** Voice Assistant/Music Player

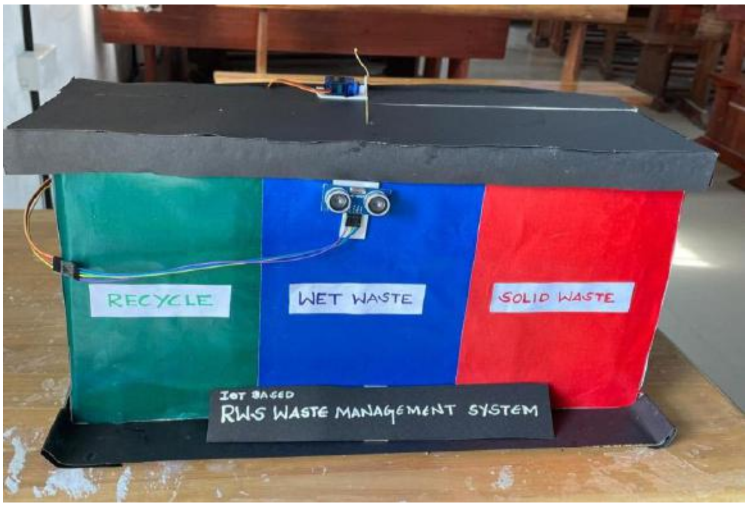

Fig 1 Prototype of our proposed model

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Phase 1: Opening and closing the lid of the dustbin

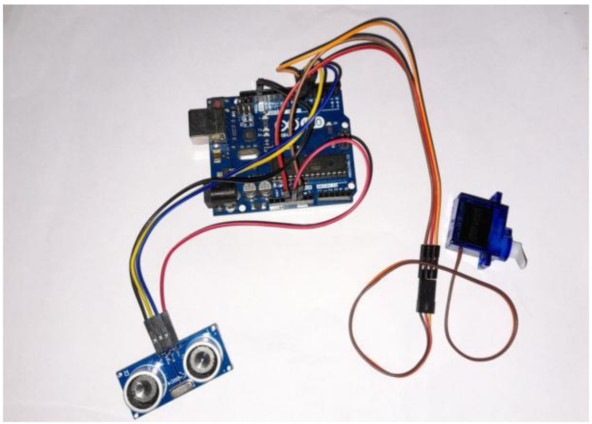

Fig 1.1 Circuit Connection for open and close the lid

Components used:

- Arduino Uno
- Servo Motor
- Ultrasonic Sensor

Result: It works on the principle of object detection using an ultrasonic sensor. The ultrasonic sensor transmits sound waves. These waves get reflected whenever an object comes into the vicinity of the sensor. This generates an electrical signal, and the servo motor will help open the dustbin lid.

Phase 2: Garbage Monitoring System

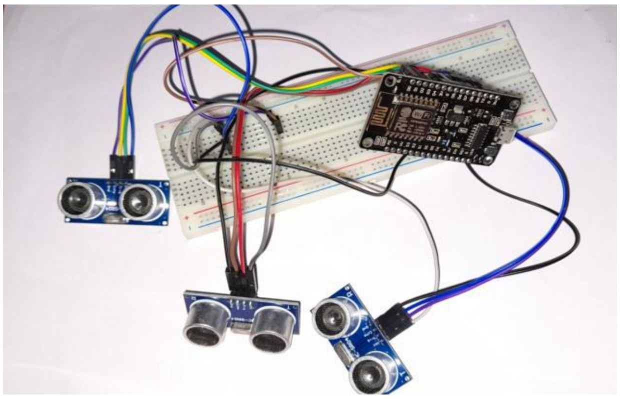

Fig 1.2 Garbage Monitoring System Circuit Construction

Components used :

- Ultrasonic sensors
- NodeMCU (ESP8266)
- Breadboard

Result: The monitored data is pushed into Thingspeak. It is an IoT cloud platform where you can send sensor data to the cloud. You can also analyze and visualize your data with MATLAB or other software, including making your own applications. The ThingSpeak service is operated by MathWorks. If the garbage is greater than 75 percent, it will send an alert message to respective authorities to collect the garbage in time.

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Graphical representation of **Recycle waste, Wet waste, Solid waste:**

Fig 1.2.1 Level and graphical representation of the **Recycle waste**

Fig 1.2.2 Level and graphical representation of the **Wet waste**

Fig 1.2.3 Level and graphical representation of **Solid waste**

Phase 3: Alert Message

Fig 2 Email Notification

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Result: If garbage level exceeds 75% then it will send the alert message to the respective authorities for collecting the garbage with the help of IFTTT (If This Then That) web service platform. Google map is attached with the email ,which will help to locate the dustbin for garbage collectors.

Phase 4: Voice Assistant/Music Player

Fig 3 ISD1820 Voice Recorder

Result: It is for voice assistance, which helps the users by assisting them in proper disposal as well as for greeting purposes. It is also used as a music player which can be used for interactive and for fun having a musical element can make using the dustbin a more engaging activity and a website provides public access to real-time bin data, promoting transparency and community engagement in waste management.

6. DISCUSSION

The IoT-based RWS waste Management System provides an innovative solution to long-standing urban waste management issues such as inefficient collection schedules, unsanitary environments, and low community engagement. By combining smart technologies and IoT capabilities, the system has shown considerable gains in waste management, operating efficiency, and environmental effect.

The results reveal that the RWS system can efficiently monitor garbage in real time and enable contactless disposal of recyclable, moist, and solid waste using automated, sensor-equipped bins. By selecting a 75% fill threshold, our system optimizes collection timing, ensuring that bins are only collected when needed. Furthermore, establishing a two-day time-based requirement for bins under 55% capacity tackles possible problems with decomposing wet trash, resulting in a cleaner and odor-free environment. The ultrasonic sensors and microcontroller arrangement were successful in correctly measuring bin levels, allowing for continuous, real-time data updates on Thingspeak and decreasing the need for manual trash checks.

Previous research on IoT-based waste management systems concentrated on improving bin capacity without paying close attention to waste segregation or the impact of time-based considerations, particularly for moist trash. In contrast, our system's multi-bin configuration with differentiable thresholds provides a more thorough approach to waste categorization and management. Our integration of the ISD1820 voice assistant offers an instructive and interactive layer that is consistent with current IoT development trends, which emphasize user contact as critical for effective system adoption. Compared to traditional methods, our solution is consistent with smart city principles since it not only automates trash management but also provides publicly accessible, real-time data to encourage community interaction.

This approach has significant implications for the management of urban sanitation. Waste management authority can minimize operational expenses by avoiding needless collection trips with IoT-based

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automation, resulting in lower fuel usage, pollution, and traffic congestion. This technology-driven strategy corresponds with the smart city goal of optimizing resources while promoting environmental sustainability. Furthermore, the system's public website serves as an educational resource, keeping citizens up to date on trash management procedures in their towns. This could encourage more appropriate garbage disposal habits and assist community-led cleanliness programs.

More reliable communication methods, such as LPWAN or 5G, may be investigated in future studies to improve data transmission dependability in places with spotty Wi-Fi coverage. The system could accommodate a greater range of waste management needs if it were expanded to cover other waste types, such as hazardous items. The efficiency of collection could be further increased by integrating machine learning algorithms to forecast garbage generation patterns based on real-time data. Finally, by lowering reliance on external power sources, solar-powered microcontrollers could increase the system's sustainability.

To improve sanitation standards and encourage public participation in garbage management, this system can be put into place in busy public places, apartment buildings, or commercial spaces in an urban setting. This technology gives city officials a more efficient way to keep an eye on and collect waste, distribute resources more wisely, and include the public in cleanliness campaigns. Transparency and community accountability are fostered by enabling residents to monitor trash management initiatives in their locality through the use of real-time notifications and public data access.

Overall, the IoT-based RWS Waste Management System demonstrates how smart technology can improve urban sanitation by providing a solution that is not only efficient and cost-effective, but also user-friendly. By overcoming the limits of traditional waste management and connecting with smart city principles, this approach has the potential to promote sustainable urban life and healthier communities. Future innovations and adjustments will increase its flexibility and sustainability, enabling smarter, cleaner cities.

7. LIMITATIONS

- **Poor Network Connectivity**: The system relies on stable Wi-Fi connectivity to transmit data. Areas with poor network coverage may experience delays in real-time updates and alerts.

  Solution: Implement a fallback mechanism using SMS or local alerts. For areas with unreliable internet, you could integrate a GSM module to send SMS alerts, ensuring that waste collection authorities are notified even without internet access.

- **Maintenance and Technical Issues**: Routine maintenance is required for components such as sensors and microcontrollers. Technical issues, including sensor calibration and hardware malfunctions, could disrupt the system's functionality.

  Solution: Implement a regular maintenance schedule, along with a remote monitoring system to identify issues early. Train local staff to perform basic troubleshooting and have readily available spare parts to minimize downtime..

- **Power Supply Requirements**: The system requires a consistent power supply, making it challenging to implement in areas without reliable electricity. Battery-powered options may require frequent replacements or recharging.

  Solution: Use solar panels or other renewable energy sources to provide continuous power, reducing the need for manual battery replacement. This would make the system more sustainable and lower its maintenance needs.

ISBN: 978-81-976827-5-9

- **User Behavior Challenges:** Effective waste disposal still depends on users correctly using the system. Misuse, such as overloading bins or placing incorrect materials, can impact the system's accuracy and performance.

  Solution: Include user-friendly prompts through the voice assistant and clear visual instructions to encourage proper usage. Conduct awareness campaigns to educate users on the system's importance and benefits.

- **Environmental Impacts:** The system's components, including sensors, batteries, and microcontrollers, contribute to electronic waste over time and may have environmental impacts if not disposed of properly.

  Solution: Use weather-resistant materials and housings to protect the sensors and microcontrollers. Implement temperature control mechanisms where possible, and regularly inspect outdoor installations to ensure they remain resilient to environmental changes.

8. FUTURE SCOPE

There are many chances to improve urban sanitation using the IoT-based RWS Waste Management System, which has a lot of room to grow and develop in the future. Future development priorities include:

- **Integration with AI and Machine Learning :** The system can forecast trash creation trends, dynamically optimize collection routes, and increase waste segregation accuracy by integrating AI and machine learning. This would improve system efficiency and further save operating expenses.
- **Intelligent Recycling and Waste Segregation:** In order to separate garbage at the collection locations using sensors and artificial intelligence (AI), future systems may incorporate automated sorting technology. This would increase recycling rates and lessen reliance on landfills by guaranteeing that recyclable items are sorted without human intervention.
- **IoT and Blockchain for Transparent Waste Management :** Transparency and traceability in waste management procedures might be guaranteed by combining blockchain technology with Internet of Things sensors. This would guarantee accountability, give tamper-proof waste management records, and lessen improper handling or unlawful dumping.
- **Global Implementation and Standardization :** International standards and protocols are being developed to guarantee consistency and best practices in trash management across cities, and the success of IoT-based waste management systems in urban settings may result in their broad acceptance on a worldwide scale.
- **Energy Generation from Waste :** Future research may examine increasingly complex waste-to-energy (WTE) systems that are connected to the Internet of Things. Cleaner energy solutions for cities may be achieved by optimizing energy extraction processes through waste quality and composition monitoring.

These further possible advancements demonstrate the adaptability and scalability of IoT-based waste management systems, guaranteeing their capacity to meet upcoming demands in resource efficiency, environmental sustainability, and urban cleanliness.

9. CONCLUSION

By using smart technology to automate and optimize garbage disposal, the Internet of Things-based RWS garbage Management System provides a revolutionary approach to urban waste management. With its multi-bin configuration for solid, wet, and recyclable garbage, this technology successfully tackles issues with sanitation, collection efficiency, and real-time waste monitoring. The findings show

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that employing a two-day time-based criterion and a 75% fill threshold for waste collection greatly lowers collection frequency while preserving environmental hygiene, which in turn lowers the need for labor, fuel, emissions, and traffic congestion.

Key IoT components, such as microcontrollers, ultrasonic sensors, and Thingspeak for data visualization, enable authorities to remotely monitor garbage levels and make fast, data-driven waste management choices[13]. Additionally, the website designed to allow the public to examine real-time bin data encourages openness, raising public knowledge of waste management procedures and encouraging appropriate disposal methods. Even though certain drawbacks were identified, such connectivity and sensor issues, they offer insightful information for further improvements, such as investigating alternate communication methods and extending waste classification capabilities.

In conclusion, this system not only improves the efficiency of urban waste management but also aligns with smart city objectives by promoting sustainability, reducing environmental impact, and supporting community engagement. With further research and technology integration, the RWS Waste Management System holds promise for significantly contributing to the development of cleaner, smarter, and more sustainable urban spaces.

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Enhancing recommendation accuracy through meta-level hybrid approaches

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Abstract: *Recommendation systems are very important in the rapidly developing field of e-commerce since they improve user experiences and increase revenues. Even if they work well, traditional strategies like content-based and collaborative filtering have drawbacks including data sparsity and the cold start issue. Combining different recommendation algorithms has led to the development of hybrid recommendation systems as a potential solution to these problems. This research provides a meta-level hybrid strategy that uses a meta-learning framework to incorporate deep learning models, content-based filtering, and collaborative filtering. We use a gradient-boosting machine for meta-learning optimization after training the model and pre-processing the data. Our suggested method performs better than individual base models and basic hybrid combinations on the MovieLens and Amazon product reviews in terms of precision, recall, F1-score, and mean squared error, according to experimental evaluations. The outcomes demonstrate how well the meta-model can combine the advantages of each base model, greatly improving suggestion accuracy. This work highlights the potential of meta-level hybrid systems to deliver precise, tailored recommendations and points to directions for future research into more effective algorithms and wider applications across many e-commerce areas.*

Key Words: *Recommendation systems, Hybrid approaches, Meta-learning, Collaborative filtering, Content- based filtering, Deep learning, E-commerce, Data sparsity, Cold start problem.*

1.INTRODUCTION

Recommendation systems[1][2] are an essential component of e-commerce platforms because they enable customers to receive personalized suggestions based on their preferences and usage patterns. These systems increases the revenue, engagement, and enhances the user experience. However, it is challenging to achieve high accuracy in recommendations due to the dynamic and diverse nature of user preferences and item features.

Although they are widely utilized, traditional recommendation systems like content-based filtering (CBF)[3] and collaborative filtering (CF)[4] have certain intrinsic drawbacks. Since CF depends on information about user-item interactions, it is vulnerable to issues with data sparsity and cold starts[5]. The quality and thoroughness of item descriptions limit the usefulness of CBF, which makes use of item attributes and user profiles. These solutions are designed to improve user experience, however, the user preferences and item attributes are dynamic and diverse, achieving high accuracy in recommendations are difficult.

Hybrid recommendation systems[6][7], which combine multiple recommendation techniques, have emerged as a promising solution to overcome these limitation. These systems combine the best features of several methodologies to produce recommendations that are more reliable and accurate. Meta-level hybrid techniques[8] are unique among hybrid systems since they maximize the merging of different

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recommendation models through the use of meta-learning. This paper explores the potential of meta-level hybrid approaches in enhancing recommendation accuracy.

2. LITERATURE REVIEW

Collaborative filtering and content-based filtering form the basis of recommendation systems. Previous interactions are used in collaborative filtering, which predicts user preferences through item- and user-based algorithms[9]. As a result of the cold start problem[10]—a lack of interaction data—CF, while successful, has trouble integrating with new users or things. Furthermore, recommendations resulting from data sparsity may not be ideal.Content-based filtering, on the other hand, recommends items by analysing the features of items previously liked by the user[11]. This method is not applicable in situations when item descriptions are inconsistent or lacking since it is highly dependent on the availability and correctness of item attributes.

Hybrid recommendation systems combine several methods in an effort to overcome these obstacles. Weighted averages, switching, and feature combining are examples of basic hybrid techniques[12]. To increase the robustness and accuracy of suggestions, more sophisticated techniques have been adopted, such as stacking and ensemble learning. Meta-learning[13], a technique where a meta-model is learned to maximize the performance of base models, has shown promise in different machine learning applications. Meta-learning can be applied to recommendation systems to aggregate the predictions of various models and take advantage of their unique advantages to improve overall performance[14]. This study is motivated by the under-researched potential of meta-learning use in recommendation systems.

3. OBJECTIVES :

The purpose of the paper "Enhancing Recommendation Accuracy through Meta-Level Hybrid Approaches" is to suggest a fresh strategy for enhancing recommendation systems' accuracy in the context of online sales. In particular, the paper presents a meta-level hybrid strategy that makes use of a meta-learning framework to combine content-based filtering, collaborative filtering, and deep learning models[15]. By utilizing the advantages of numerous models, the goal is to overcome the drawbacks of conventional recommendation systems, such as data sparsity and the cold start issue. The research aims to demonstrate that this meta-level hybrid approach can significantly enhance the precision, recall, F1-score, and mean squared error (MSE) of recommendation systems compared to individual base models or simple hybrid approaches.

The ultimate goal is to provide more accurate and personalized recommendations for users in e-commerce platforms, thereby improving the user experience and boosting sales. Additionally, the document seeks to explore further research directions, such as more efficient meta-learning algorithms and the application of the proposed methodology in a broader range of e-commerce scenarios.

4. PROPOSED METHODOLOGY

Our proposed meta-level hybrid approach integrates collaborative filtering, content-based filtering, and deep learning models using a meta-learning framework. The process involves the following steps:

- **Data Sources and Preprocessing**: We use publicly available e-commerce datasets, including user-item interaction data and item attribute data. Preprocessing steps include normalization, feature extraction, and handling missing values.

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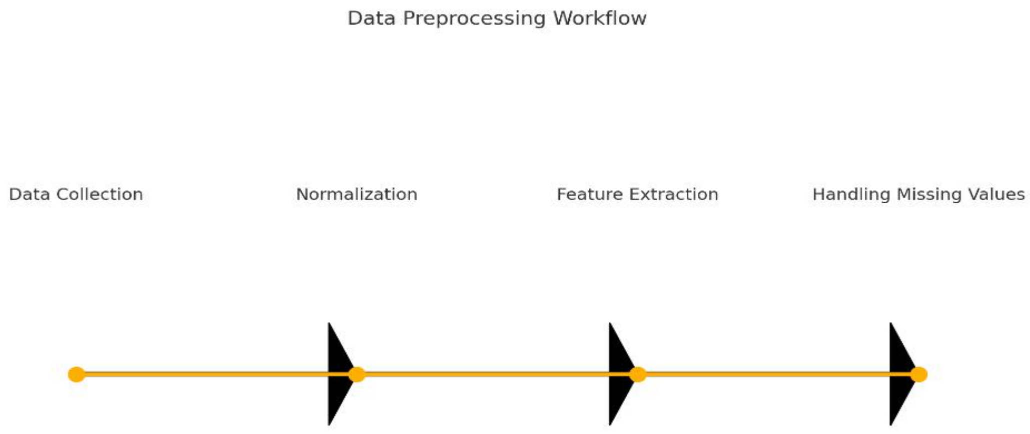

Figure 1: Data preprocessing workflow.

1. Data Collection: This initial step involves gathering raw data from various sources, such as user interactions (e.g., clicks, views, purchases), user profiles, item attributes, and external sources like reviews or social media. The data collected is often heterogeneous and unstructured, requiring subsequent processing steps.

2. Normalization: In this step, raw data is transformed into a standardized format to ensure consistency across different datasets. Techniques such as scaling numerical features, encoding categorical variables, and ensuring consistent data types are applied. Normalization helps reduce biases that might arise due to differences in scales or formats of the data.

3. Feature Extraction: Feature extraction involves selecting and transforming relevant features from the raw data that will be used for modelling. In recommendation systems, features can include user demographics, item characteristics, interaction history, and contextual information (e.g., time of interaction). Advanced techniques such as embedding representations for users and items, dimensionality reduction, and text processing (e.g., TF-IDF, word embeddings) are often used.

4. Handling Missing Values: Real-world data often contains missing values that need to be addressed before modeling. Common techniques for handling missing values include imputation (e.g., mean, median, or mode imputation), deletion of records with missing values, or using native algorithms that can handle missing data. Proper handling of missing values is crucial to prevent biases and inaccuracies in the recommendation models.

Effective data preprocessing ensures that the data fed into the models is clean, consistent, and representative of the underlying patterns. This leads to better model performance, more reliable recommendations, and improved user satisfaction in e-commerce platforms.

- **Model Architecture**: The base models include matrix factorization [16] for collaborative filtering, a neural network[17] for content-based filtering, and a hybrid deep learning model [18][19] that combines both techniques. The meta-model is a gradient-boosting machine [20] trained to optimize the predictions of the base models.

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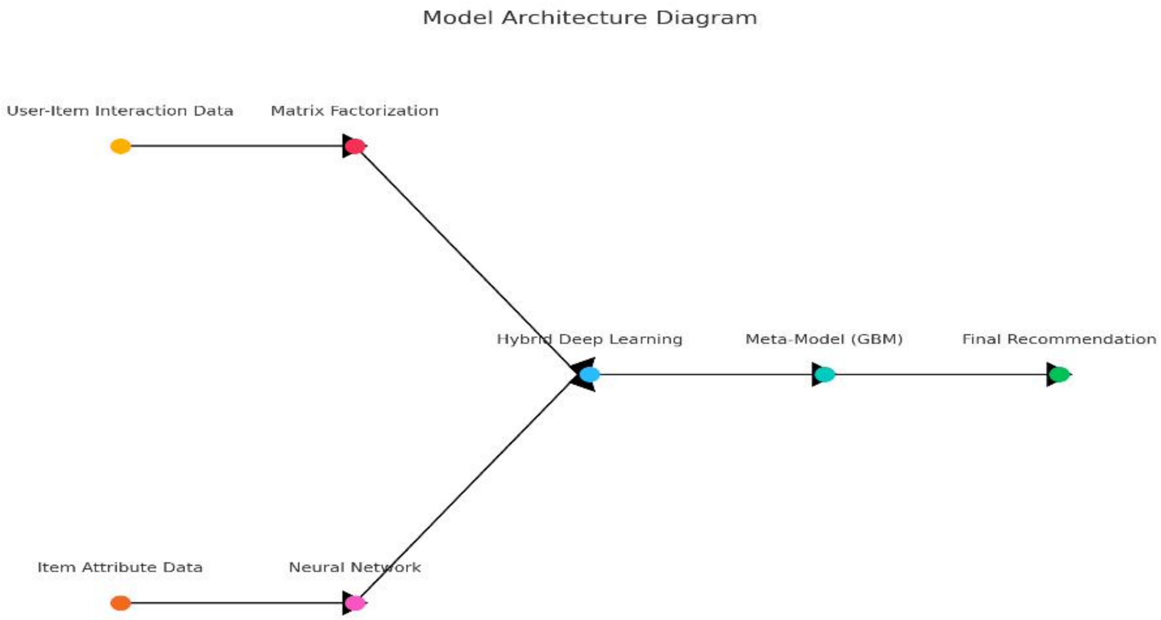

Figure 2: Model architecture diagram

Model Architecture Diagram

The model architecture diagram outlines the flow and interaction between different components of the meta-level hybrid recommendation system[20]. Each component plays a crucial role in the process of generating accurate recommendations. Here is a detailed explanation of each component and its function:

1. **User-Item Interaction Data**:
   - This component represents the data collected from user interactions with items, such as clicks, views, ratings, and purchases. This data is essential for understanding user preferences and behavior patterns.
2. **Item Attribute Data**:
   - This component includes data related to the attributes of items, such as product descriptions, categories, prices, and other relevant features. This information helps in understanding the characteristics of the items being recommended.
3. **Matrix Factorization**:
   - Matrix Factorization (MF) is a collaborative filtering technique[21] used to predict user preferences by decomposing the user-item interaction matrix into latent factors. These latent factors represent the underlying characteristics of users and items, allowing for accurate predictions even with sparse data.
4. **Neural Network**:
   - A neural network model is employed for content-based filtering[22]. It learns complex patterns and relationships in the item attribute data, enabling the recommendation system to make predictions based on item similarities and user profiles.
5. **Hybrid Deep Learning**:
   - This component combines the outputs of the matrix factorization and neural network models. By integrating collaborative filtering and content-based filtering, the hybrid

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deep learning model leverages the strengths of both approaches to provide more accurate recommendations[23].

6. **Meta-Model (Gradient Boosting Machine - GBM)**:
   - The meta-model[24][25], typically implemented as a Gradient Boosting Machine (GBM), is trained to optimize the combination of predictions from the hybrid deep learning model. It learns the optimal way to weight and combine the base model outputs to enhance the overall performance of the recommendation system.
7. **Final Recommendation**:
   - The final recommendation component generates the list of recommended items for each user based on the optimized predictions from the meta-model. This step ensures that the recommendations are accurate and personalized, leading to improved user satisfaction and engagement.

Flow of Information:

- The user-item interaction data is fed into the matrix factorization model.
- The item attribute data is processed by the neural network.
- Both the matrix factorization and neural network models contribute their predictions to the hybrid deep learning model.
- The hybrid deep learning model's output is further optimized by the meta-model (GBM).
- The meta-model generates the final recommendation list for users.

By combining multiple recommendation techniques at a meta-level, this architecture leverages the strengths of each component, resulting in improved recommendation accuracy and robustness.

5. EXPERIMENTS AND RESULTS

To evaluate the effectiveness of the proposed approach, we conducted experiments using the MovieLens and Amazon product review datasets. These datasets provide diverse user interactions and item attributes, making them suitable for testing our approach.

- **Experimental Setup**: We split the data into training, validation, and test sets, ensuring a representative distribution of user interactions and item attributes.

Table 1: Data split statistics

Dataset	Training Set	Validation Set	Test Set
Movie Lens	70%	15%	15%
Amazon views	70%	15%	15%

Datasets Used: The MovieLens dataset contains movie ratings from users, while the Amazon product review dataset includes user reviews and ratings for various products.

Table 2: Dataset characteristics

Dataset	Users	Items	#Interactions	
MovieLens	1,00,000	10,000	10,00,000	
Amazon Reviews	5,00,000	50,000	50,00,000	

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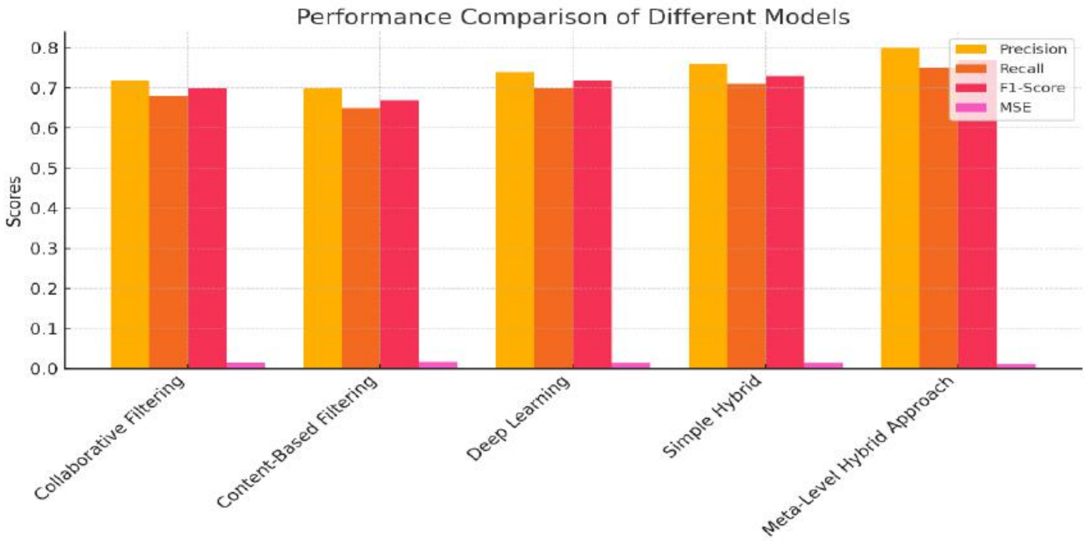
- **Comparison with Baseline Models**: We compare our meta-level hybrid approach with individual base models (collaborative filtering, content-based filtering, and deep learning) and simple hybrid combinations.

- **Evaluation Metrics**: We use accuracy metrics such as precision, recall, F1-score, and mean squared error (MSE) to evaluate the performance of the models.

Figure 3: Performance comparison of different models.



The chart compares the performance of different recommendation models using four key metrics: Precision, Recall, F1-Score, and Mean Squared Error (MSE). Each model is evaluated based on these metrics to assess its effectiveness in providing accurate recommendations.

Models Compared

1. Collaborative Filtering
2. Content-Based Filtering
3. Deep Learning
4. Simple Hybrid
5. Meta-Level Hybrid Approach

Metrics Used

1. **Precision** (Yellow Bars)
    - Measures the proportion of relevant recommendations out of the total recommendations made.
    - Higher precision indicates that more of the recommended items are relevant to the user.
2. **Recall** (Orange Bars)
    - Measures the proportion of relevant items that have been recommended out of all relevant items available.
    - Higher recall indicates that the model is able to recommend most of the relevant items.
3. **F1-Score** (Red Bars)
    - The harmonic mean of precision and recall, providing a balance between the two.

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- Higher F1-Score indicates a good balance between precision and recall, reflecting the overall effectiveness of the model.

4. **Mean Squared Error (MSE)** (Pink Bars)
    - Measures the average squared difference between the predicted ratings and the actual ratings.
    - Lower MSE indicates higher accuracy in the predicted ratings.

ANALYSIS:

- **Collaborative Filtering**:
    - Shows moderate precision, recall, and F1-Score.
    - MSE is relatively higher, indicating less accurate predictions compared to other models.
- **Content-Based Filtering**:
    - Slightly lower precision and recall compared to collaborative filtering.
    - F1-Score is also lower, with the highest MSE among the models, indicating less effective recommendations.
- **Deep Learning**:
    - Higher precision, recall, and F1-Score compared to both collaborative and content-based filtering.
    - MSE is lower, showing more accurate predictions.
- **Simple Hybrid**:
    - Combines collaborative and content-based filtering, leading to improved precision, recall, and F1-Score.
    - MSE is lower than individual filtering methods, indicating better overall performance.
- **Meta-Level Hybrid Approach**:
    - Demonstrates the highest precision, recall, and F1-Score among all models.
    - MSE is the lowest, indicating the most accurate predictions.
    - This approach effectively leverages the strengths of multiple models, resulting in superior performance.

The chart clearly shows that the Meta-Level Hybrid Approach outperforms other models in all metrics, providing the most accurate and relevant recommendations. This highlights the advantage of combining multiple recommendation techniques to improve overall performance. The Simple Hybrid model also shows significant improvements over individual collaborative and content-based filtering methods, demonstrating the benefit of hybrid approaches in recommendation systems

The meta-model's role is to learn the optimal combination of the base models' predictions, enhancing the overall recommendation accuracy. By leveraging the strengths of each base model, the meta-level hybrid approach aims to provide more accurate and personalized recommendations.

Results and Discussion: Our approach outperforms the baseline models in terms of accuracy metrics. The meta-model effectively leverages the strengths of each base model, resulting in more accurate recommendations.

Table 3: Performance metrics.

Model	**Precision**	**Recall**	**F1-Score**	**MSE**	
Collaborative Filtering	0.72	0.68	0.7	0.015	
Content-Based Filtering	0.7	0.65	0.67	0.017	

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Deep Learning	0.74	0.7	0.72	0.014	
Simple Hybrid	0.76	0.71	0.73	0.013	
Meta-Level Hybrid Approach	0.8	0.75	0.77	0.011	

The results demonstrate that the meta-level hybrid approach significantly improves recommendation accuracy compared to individual base models and simple hybrid combinations. The meta-model's ability to learn the optimal combination of base model predictions is key to its superior performance.

6. DISCUSSION

The experimental results highlight the effectiveness of the meta-level hybrid approach in enhancing recommendation accuracy. The meta-model's ability to optimize the combination of base models' predictions results in more accurate and personalized recommendations. However, the approach faces challenges such as increased computational complexity and the need for extensive hyperparameter tuning.

Future research could explore more efficient meta-learning algorithms and the integration of additional data sources, such as contextual information and social network data. Additionally, addressing the scalability of the approach is crucial for its practical application in large-scale e-commerce systems.

7. CONCLUSION

This paper presents a meta-level hybrid approach to enhance recommendation accuracy in e-commerce systems. Our findings indicate that meta-learning can effectively combine multiple recommendation techniques, leading to improved performance. The implications for future research include the exploration of more efficient algorithms and broader applications in various domains of e-commerce.

The proposed approach demonstrates the potential of meta-level hybrid systems in providing accurate and personalized recommendations, highlighting the importance of leveraging multiple techniques to address the diverse and dynamic nature of user preferences and item attributes.

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Optimizing Maritime Routes for Sustainability: A Machine Learning Review

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Abstract: *Marine transportation is essential for conducting global trade. But it is one of the greatest contributors of greenhouse gas emissions. Various methods put forward by machine learning can be used to control pollution, reduce fuel consumption, and lessen travel time. Therefore, it becomes a necessity to find out better maritime routes which resolve the issues. This paper studies the latest approaches in machine learning that can be used for sustainable maritime transportation giving emphasis to heuristic approaches, Radial Basis Function, Neural Networks (RBFNN), and the Whale Optimization Algorithm (WOA). Machine learning techniques such as Reinforcement Learning (RL) and Monte Carlo simulations can be used to model uncertainties which includes fuel prices, delays at the port and weather patterns. Sulfur dioxide emissions can be more accurately predicted using AutoML TPOT and non-linear regression. Routes can be optimized based on real time data using a three-dimensional dynamic programming algorithm. A comparison of various models such as LSTM networks and SHAP (Shapley Additive Explanations) were also performed to find factors affecting emissions in shipping. The impact of heuristic algorithms like Simulated Annealing, Asymmetric Traveling Salesman Problem and Genetic Algorithms were also studied to obtain optimized shipping routes based on fuel costs. Hybrid approaches which combined traditional optimization algorithms with machine learning methods showed better results.*

Key Words: *ML, RBFNN, WOA, RL, LSTM, SHAP*

1. INTRODUCTION:

Maritime shipping is the backbone of global trade, responsible for transporting nearly 90% of the world's goods. However, this essential industry is also a major contributor to environmental degradation, producing significant carbon emissions, sulfur oxides (SOx), nitrogen oxides (NOx), and other pollutants. As the world moves towards more sustainable practices, the International Maritime Organization (IMO) has set ambitious targets to reduce the maritime industry's carbon emissions by at least 50% by 2050 compared to 2008 levels. Achieving these targets requires innovative strategies to optimize ship operations, reduce fuel consumption, and minimize environmental impacts.

The integration of machine learning into maritime transport has gained traction in recent years, offering advanced solutions for complex problems such as route optimization, fuel efficiency, and emission prediction. This paper reviews the application of machine learning techniques in maritime transport, focusing on sustainable route planning, emission reduction, and operational efficiency. It also discuss hybrid approaches that combine machine learning with traditional optimization algorithms, addressing the inherent uncertainty in maritime operations.

As maritime shipping faces increasing pressure to adopt greener practices, the application of machine learning is emerging as a powerful tool in enabling sustainable, data-driven decision-making.

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2. PROBLEM DEFINITION

Traditional maritime route planning methods are often inefficient, leading to excess fuel consumption, longer voyage times, and higher emissions. These inefficiencies are due to limited adaptability to dynamic factors such as changing weather conditions, ocean currents, and vessel-specific operational constraints. Machine learning helps by using data to plan better routes and make shipping more efficient and environmentally friendly.

Several key challenges that confront the industry are:

1. **Fuel Consumption and Emissions**: Fuel is one of the largest operational costs in shipping, accounting for up to 60% of total expenses. Reducing fuel consumption directly correlates with lower emissions of $CO2$, SOx, and NOx, making it a critical factor in both cost management and environmental sustainability.
2. **Operational Uncertainty**: Ship routing is a complex task, influenced by unpredictable factors such as weather, sea conditions, port congestion, and fuel price volatility. These uncertainties make it difficult to plan optimal routes that minimize fuel consumption and emissions while ensuring timely delivery.
3. **Data-Driven Decision Making**: The increasing availability of real-time data from onboard sensors, weather forecasts, and port conditions presents opportunities to optimize ship operations. However, the vast amounts of data generated require sophisticated analysis to extract actionable insights.
4. **Safety and Security**: With the advent of digital technologies in shipping, cybersecurity has become a critical concern. Securing data transmission between ships and shore is essential to ensure safe and efficient operations.

3.OBJECTIVE

This review aims to explore the role of machine learning in addressing these challenges and advancing sustainable practices in maritime transport. Specifically, the objectives are:

1. To review machine learning methods applied in maritime route optimization, fuel efficiency, and emission reduction.
2. To evaluate the effectiveness of hybrid models that integrate machine learning with optimization algorithms in addressing maritime operational uncertainties.
3. To provide insights into the future potential of machine learning in contributing to sustainable maritime transport, highlighting areas for further research and development.
4. To analyze the security aspects of machine learning applications in maritime transport, focusing on data integrity and cybersecurity in ship operations.

4. METHODS OR ALGORITHMS USED

1. Deep Learning-Based Discrete Weather Data Continuuousization Model

In this approach, a Convolutional Neural Network (CNN) is used to extract spatial features from historical weather forecast data. These features are then converted into one-dimensional vectors using a fully connected layer and fed into a Transformer model to capture the temporal patterns of the weather data. This results in a weather forecast model that integrates both spatial and temporal information. Spatial weather data focuses on weather patterns across different locations. Temporal weather data

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focuses on how weather changes over time. Both types are crucial for weather forecasting, as they capture the full picture of weather dynamics in both space and time.

The weather data generated by this model is then used to enhance the accuracy of future weather predictions. The effectiveness of the method is demonstrated by comparing the differences between the routes optimized with the initial weather forecasts and those optimized with the improved forecasts.

2. Radial Basis Function Neural Network (RBFNN) and Whale Optimization Algorithm (WOA)

The combination of a Radial Basis Function Neural Network (RBFNN) and the Whale Optimization Algorithm (WOA) provides a powerful hybrid approach for optimizing shipping routes. It uses the modeling capabilities of neural networks and the optimization strengths of WOA. Initially, parameters like speed log, thrust, position etc. are sensed from ship using sensor. The gathered data is transferred to IoT interface for further transformation into cloud. Information transfer within cloud has the chance for cyber-attack. This method introduced Two Fish based 128-bit cryptographic key management system for transferring data with security. To transfer data at the earliest shortest path is made easier in this approach with the adoption of WOA based RBFNN classifer.

RBFNN prediction: Based on current and forecasted weather data, ocean currents, and the ship's specifications, the RBFNN predicts how different routes will impact fuel consumption, time, and safety. WOA optimization: WOA generates multiple possible routes and evaluates each one using the RBFNN's predictions. The algorithm then refines these routes, looking for the most efficient path that avoids bad weather and optimizes fuel use.

3. Three-dimensional dynamic programming (3DDP)

Dynamic programming (DP) is a method given to solve complex problems by breaking them down into smaller, simpler subproblems and solving them recursively. Three-dimensional dynamic programming (3DDP) extends this concept to optimize problems involving three dimensions, which, in the case of ship route optimization, could be:
Geographic space: The ship's position (latitude and longitude).
Time: The time dimension to account for the changing conditions (e.g., weather or sea state).
Environmental conditions: Such as weather (wind, waves, currents) that change dynamically across different locations and times.

Steps to Apply 3DDP for Ship Route Optimization:

The ship's route is divided into a grid or network of waypoints, where each waypoint is a possible location the ship can visit at a specific time. The ship needs to move from the starting point (e.g., a port) to the destination (another port) by choosing the best path through this grid. Each waypoint in the grid has associated costs (e.g., fuel consumption, travel time, or risk due to bad weather). Starting from the destination, the algorithm works backward to determine the best path to the destination from each potential waypoint. At each step, the cost of moving from one waypoint to another (considering time and weather) is calculated, and the minimum cost is selected for each subproblem. This continues until the starting point is reached, resulting in a globally optimal path. At each decision point (each waypoint in time), the algorithm evaluates new weather data to ensure the route remains optimal and safe (dynamic updates).

4. Auto ML TPOT Framework

Automated Machine Learning (AutoML) is a term used to describe strategies that automate the process of identifying high-performing models for predictive modeling tasks with very low human intervention. One notable Python-based open source library for AutoML is TPOT. TPOT emerged as the top-performing model for predicting SO_2 emissions due to its ability to efficiently find the best regression model. Here's how it works in simple terms:

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Automated Process: It tests a variety of models, like decision trees or regression models, and finds the one that works best for your specific task.

Genetic Programming: TPOT uses an approach inspired by evolution. It combines different models, tweaks their settings (called hyperparameters), and then "evolves" them over several generations. The best models are kept, and weaker ones are replaced, just like in natural selection.

Pipelines: TPOT doesn't just choose the model; it also builds the entire workflow, from preparing the data (like cleaning and transforming it) to selecting the model and setting the right parameters. This complete process is called a "pipeline."

Optimization: By using this evolutionary approach, TPOT continuously searches for better models and settings until it finds the combination that gives the best results.

5. LSTM (Long Short-Term Memory) for Prediction

LSTM is a type of Recurrent Neural Network (RNN) designed to process sequential data, making it suitable for time-series prediction tasks like ship fuel consumption and emission forecasting. Route Optimization: By predicting future fuel consumption and emissions based on real-time data, LSTM models allow ship operators to optimize routes. For example, ships can avoid areas with higher fuel demands (e.g., rough sea conditions or areas requiring higher speeds) and select routes that minimize fuel consumption.

Proactive Planning: LSTM can forecast fuel consumption for different segments of a planned route, allowing ship operators to adjust speed, operational mode (diesel or gas), and other factors to lower overall emissions.
Various factors, such as weather conditions, ocean currents, and ship speed, influence a vessel's fuel consumption, creating temporal patterns. LSTM effectively captures these temporal characteristics in time series data, enabling learning from past data to predict future fuel consumption.

6. SHAP (Shapley Additive Explanations)

SHAP is an Explainable AI (XAI) technique based on game theory that is used to interpret the predictions of machine learning models like Random Forest or LSTM. It helps identify which features (such as ship speed, draft, wind direction) are most important in predicting fuel consumption.

Feature Importance for Route Planning: For ship route optimization, knowing which operational factors (e.g., speed, wind, trim) most significantly affect fuel consumption helps operators make informed decisions. For example, if SHAP shows that ship speed has the highest impact on fuel usage, operators can prioritize speed adjustments in different segments of the route to reduce emissions.

Insights for Emission Reduction: SHAP analysis shows how various factors (like wind direction or water depth) influence fuel consumption. Operators can use these insights to select routes that minimize the impact of adverse conditions, thus lowering emissions. For instance, avoiding routes with strong headwinds could significantly reduce fuel consumption.

5.CONCLUSION

Machine learning offers a powerful tool for improving sustainability in maritime transport. From optimizing routes and fuel consumption to predicting emissions and managing operational uncertainty,

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machine learning models can enhance the efficiency and environmental performance of shipping operations. Hybrid approaches that combine machine learning with traditional optimization algorithms show particular promise, offering the flexibility needed to adapt to changing sea conditions and operational demands.

However, challenges remain in areas such as data acquisition, uncertainty modeling, and cybersecurity. As the maritime industry continues to evolve, further research is needed to refine machine learning techniques and integrate them into broader sustainability efforts.

By embracing these technologies, the maritime industry can not only reduce its environmental impact but also improve operational efficiency, ensuring that shipping continues to serve as the lifeblood of global trade while minimizing its ecological footprint.

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Analysis and Accuracy of Filtering Techniques in Computer Vision

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Abstract. *Image analysis is one of the growing technologies in today's world. The images are now a days obtained from various sources. These sources may range from a number of devices. The image that is captured is also considered under various environments that may not provide the clear details of the image. The details of the image may not be obtained leading to misleading facts. Certain type of filtering techniques need to be applied to obtain a more clear image and obtain an understanding of the image to get complete data. The filtering techniques remove noise from the data and obtain the data. This will solve most of the problems that arise when the images are taken under different circumstances and provide with a solution.*

Keywords: *Filter, Mean, Median, Guassian, Fourier Transform.*

1. INTRODUCTION

1.1 Computer vision and image filtering

Computer vision can be defined as a branch of computer science that deals with the capturing of the images and the processing of the images to produce efficient results. An image can be defined as a combination of pixels where a pixel is small tiny component. When a large number of pixels are joined together, we get an image. Computer vision deals with the extraction of useful data from the image[1].Every image has certain information stored in it and computer vision aids to extract that information from the image .Now the quality of the image , the background of the image , the noise in the image are some of the factors that are affecting the quality of the image .All these have to be re designed to extract a good quality image .This can de stated as the main aim of computer vision.

Images can be obtained from a variety of different sources this may deal from various camera capturing images to different iot based images that are installed in a different environment [2]. An iot can be defined as a combination of devices and sensors that are portable and have the capacity to store and analyze the information. The devices are helpful not only in the field of home security but also much more useful in agriculture [3]. The image that are captured from these devices may not be clear at certain instances and need to filtered to get the exact image. The images may have to monitored over the cloud to be able to be retrieved and gather the information. In a cloud environment there may be number of images that are sent to the machine and all these images have to be analyzed.

Filtering can be defined as the process of removing the noise from the image to gain an access to the needful information. Image filtering is persistent in our day to day lives where we encounter a lot of images that need to be altered to find the exact picture. The process of filtering does not change the position of the pixels but only changes the val- ues of the pixel.

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By changing the values of the pixel the image might become more clear or brighter in the view of the image. Now apart from altering the image we also need to find certain pieces of information from the image. This can be ranging from edges, corners, object detection etc.

This information might be of incredible evidence to find the information from an image. All the information from the image can be obtained from the from the image analysis and filtering helps us to get this information. There are different types of filtering techniques that are available to help in proper analysis of the image. Some of the filtering methods that can be adapted are gaussain filtering, mean filtering, sobel filtering, median filtering etc.

The type of filtering that can be applied depends on the application or the objective that needs to be achieved.

2. Analysis.

There are two types of filtering of algorithms. They are linear filtering and non-linear filtering. The pixel are used to identify the image. The intensity of the pixel identifies the level of intensity of the image. The linear filtering focuses on the neighboring pixels and changes the value of the pixels to modify the image. Now the location of the pixels are identified based on the image enhancement that is required.

If the level of noise associated with the image is low and the dimensions of the image is very high then then the filtering that is used is nonlinear filtering. The filtering techniques apply certain changes to the image that may deal with blur images or smoothing effect on the images and apply the techniques to produce enhanced results.

Gaussian Filter

Gaussian filtering is one of the most widely used filtering techniques used for the pro- cessing of the images in the field of computer vision. Noise is considered as one of the most important phenomena in regard to the distortion of the images. It adds to the different types of problems that can be considered while the image is not clearly visible. At the same time the distortion also does not provide the clear understanding of the image. Even the edge of the images can also be difficult to be achieved. Not only for the filtering but also for the edge detection and processing the gaussian filtering can be used. This filtering provides the edge and the picture with regard to the edge detection.This can be applied for the edge displacement and the vanishing of the edges. The filtering helps to solve the problems of image distortion by applying the different types of techniques for filtering [4].

Original image *filtered image*

Mean Filter

The common noise that can be observed in the transmission of the images is the problem that occurs during the acquisition of the image. This acquisition of the image can be obtained from the different environments that may affect the capture of the image. Hence the capturing of the image within different environments is responsible for the image and its different problems.

The Mean filter is one of the main methods used for providing the removal of noise [6]. It considers the neighboring of the pixel and the value that is associated with the pixels. Each pixel has a certain amount of value that can be used to identify the image. The mean filtering replaces the values of the

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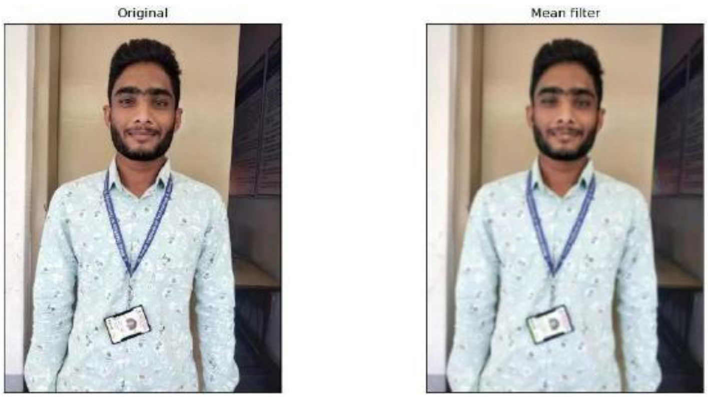
pixel of the original image with the value of the neighboring pixel image. The mean value of the pixels are determined and the values are replaced from the value of the pixel. The image that is obtained from the filtering will be of a low intensity as the values of the pixel may be changed. This change of the value of the images may affect the intensity of the image.

Median filter

The mean filtering causes for the blurring of the image which may lead to the invisible edges. This blur of the image may result in a lot of distortion to the images. Even though it changes the value of the pixel but it may cause for non-clear images to appear. The value of pixel is replaced by the median value of the pixels to produce a clear image. The process of segmentation can also be analyzed by using median filter. The median filter is a nonlinear that is very simple and also it very fast for the processing of the image.



Fourier Transform

Fourier transform is technique that is used in the field of mathematics. It also pro- vides for the single image analysis and also finds its application in the field of signal processing and image processing. Fourier transforms find its applications in various processing of the images as it requires very less time for the analysis of the image. Every image has a number of counts which indicates the frequency of the image. This count of the frequency can be very well analyzed by using the Fourier transform. The Fourier transform is performed on the number of rows and columns. The number of frequencies of the image can be analyzed further to reduce an effect of the image. It also important for extraction of features and also edge connections.

ISBN: 978-81-976827-5-9

3. Results:

The following are the accuracy results that are obtained when the different types of filters are run using the above images.

Table 1. Accuracy.

Sno	Filter	Accuracy
1)	**Mean**	**25**
2)	**Median**	**25**
3)	**Fourier**	**39**
4)	**gaussian**	**30**

(1)

The following is the graphical representation of the above results.

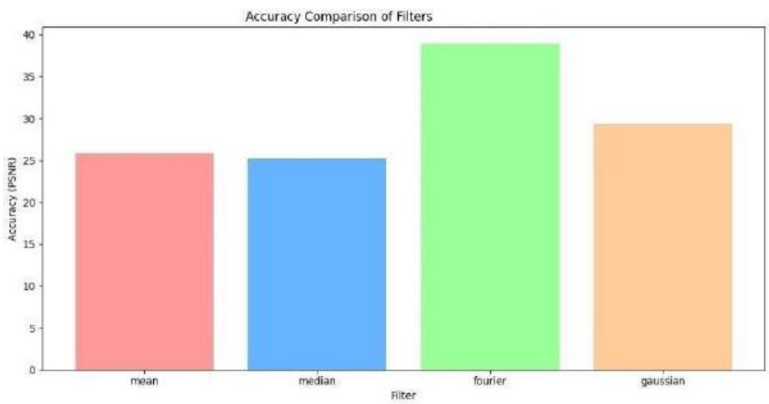


Fig. 1.Accuracy results for the different types of filters

ISBN: 978-81-976827-5-9

4. Conclusion:

The recent advances in the field of computer vision enabled the use of deep learning methods to obtain better results. The filtering options can be improved to a greater ex- tent by using the different deep learning algorithms and obtain better results.

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Evaluating the Impact of Problem-Based Learning in Programming Courses

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Abstract: *Computer programming is a fundamental aspect of engineering education, yet it often presents significant challenges due to its emphasis on problem-solving skills. Proficiency in programming is crucial for the development and implementation of various technologies, serving as a key indicator of a software developer's professional capabilities, and graduates with strong programming skills typically enjoy a competitive edge in the job market. This paper explores the use of Action Research (AR) methodology to enhance engineering students' programming and problem-solving abilities through an intervention class that employs the Problem-Based Learning (PBL) approach. By integrating real-world problems into the learning experience, the PBL approach fosters deeper engagement and understanding among students. We conducted evaluations to assess the effectiveness of this instructional strategy, focusing on student performance and attitudes towards programming. Preliminary findings indicate that the PBL approach not only improves technical skills but also enhances students' confidence and motivation. Through reflective practice and continuous feedback, this study aims to provide valuable insights into optimizing programming instruction within engineering curricula. Our findings contribute to the ongoing discourse on effective pedagogical strategies for teaching programming and underscore the importance of equipping students with the skills necessary to succeed in a rapidly evolving technological landscape. By sharing these insights, we seek to inform educators and curriculum developers about best practices for cultivating programming expertise among engineering students, ultimately preparing them for successful careers in the field.*

Key Words: *Problem-Based Learning (PBL), programming skills, Action Research (AR) methodology*

1. INTRODUCTION:

Programming encompasses a broad array of activities and concepts, and in order to effectively write a program that can solve a problem, students must possess strong problem-solving and critical thinking skills. This presents a significant challenge for many students, especially those who are novices in programming. To successfully solve a problem, students need to first comprehend the problem itself, then devise a solution using established problem-solving strategies. Afterward, they must translate this solution into a programming language in a manner that the computer can process and execute the algorithms correctly [4]. Through the development of problem-solving skills, students learn not only how to read and understand program code, but also how to modify and adapt it to address various types of problems across different contexts.

Unlike the acquisition of theoretical knowledge, which can often be achieved through passive learning, the development of problem-solving skills requires an active, engaged approach. A passive learning

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method is inadequate for mastering problem-solving abilities, as it lacks the interactive and practical experience needed to foster these critical skills [5].

2. RESEARCH CONTEXT:

While teaching computer science courses, one of the main challenges we face is developing students' Problem-Solving and Computer Programming (PSCP) skills. Our classrooms are often composed of a diverse group of students, where some possess strong mathematical or problem-solving abilities, while others lack these foundational skills. This diversity complicates the teaching process, as students with varying levels of prior knowledge and skills often struggle to keep up with the pace of the curriculum.

Most programming modules aim to cover both the theoretical and practical aspects of a programming language. In the early stages of the course, students are typically introduced to the characteristics and syntax rules of the language. These concepts are generally straightforward and easy for students to grasp. However, as we transition into practical sessions focused on problem-solving and programming, a number of students become disengaged or unmotivated to participate in the implementation tasks. Many of these students feel that they lack the necessary problem-solving skills to understand programming logic, which creates a barrier to their learning. Interestingly, when the problem's logic is presented through visual aids such as algorithms or flowcharts, students tend to show greater interest in engaging with the problem and implementing the solution. This indicates that while students may initially struggle with the abstract aspects of problem-solving, they can better grasp the logic when it is broken down into more tangible and structured formats. This suggests that the challenge is not so much a lack of programming knowledge but rather an underdeveloped ability to use critical thinking independently to devise solutions.

As educators, the main challenge lies in cultivating these essential problem-solving skills alongside programming knowledge. Our action research demonstrates that adopting a Problem-Based Learning (PBL) approach—coupled with intervention classes designed to engage students more actively—can significantly enhance their PSCP skills. By encouraging active participation, collaboration, and critical thinking, the PBL method helps students bridge the gap between theoretical knowledge and practical application, ultimately improving their ability to solve complex programming problems.

3. PROBLEM-BASED LEARNING:

Students become active participants in their education through Problem-Based Learning (PBL). By focusing on real-world issues, PBL encourages students to develop essential problem-solving skills rather than merely memorizing facts. In a PBL project, students propose ideas and create plans to address specific problems. The key benefits of problem-based learning include:

1. Student-Centered Approach: PBL encourages students to take responsibility for their own learning. As a student-centered methodology, it fosters independence and active engagement.
2. Active Participation: Instead of passively listening, PBL places students in control of their learning. They are required to remain focused, apply critical thinking, and adopt new perspectives to solve problems.

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3. Personal Growth: The rewards of PBL extend beyond grades. As students tackle challenges and develop innovative solutions, they gain self-respect, confidence, and a deep sense of satisfaction [7].

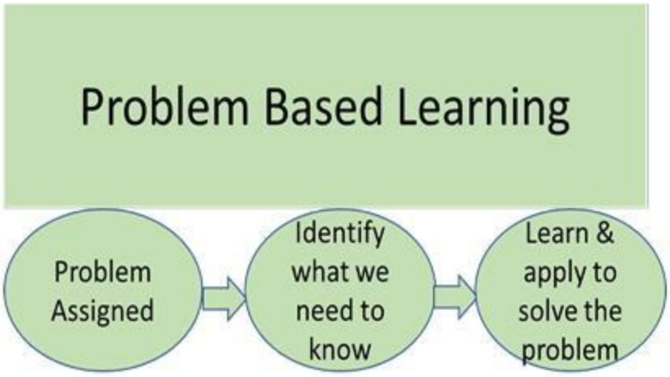

Figure 1: Problem-Based Learning[8]

4. EFFECTIVENESS OF PBL:

In PBL, students are encouraged to develop reflective, critical, and collaborative skills. In comparison with students in a lecture-based learning environment, PBL students appear to acquire similar or fewer short-term knowledge gains when it comes to short-term knowledge acquisition [9]. However, in terms of longer-term knowledge retention, the results are improved significantly in PBL's favor [10],[11]. In a recent [12] empirical study, PBL's effectiveness was further demonstrated. Groups of students were randomly assigned to one of three conditions (PBL, lecture-based, or self-study), and the authors found that students in the PBL group were more likely to demonstrate conceptual changes. In conceptual tests immediately after the lesson, as well as a delayed post-test right after a week, students in the PBL group outperformed the other two conditions [12].

5.RESEARCH OBJECTIVES:

According to the principle of Constructive Alignment, learning outcomes are carefully defined in alignment with module specifications, ensuring that all assessments and teaching activities are intentionally designed to achieve these outcomes [16]. In this research, we have adopted Problem-Based Learning (PBL), grounded in constructivist theory, as the framework for our teaching practice [17]. The PBL approach encourages students to begin their learning process by engaging with a real-world problem, question, or scenario. This is followed by four key stages in the learning cycle: 1) Understanding the Problem, where students analyze and interpret the issue at hand; 2) Learning Stage, which can be undertaken individually or in groups, where students acquire the necessary knowledge and skills; 3) Solving the Problem, where students apply their learning to develop a solution; and 4) Reflecting, where students, either individually or as a team, reflect on the learning process and the effectiveness of their solution.

The objectives of our research study were as follows: (i) To design intervention classes, scheduled within the current learning environment, lasting 5-6 weeks, to allow students to engage with PBL methods in a structured manner; (ii) To incorporate problem-solving exercises into formative assessments, enabling continuous learning and feedback; (iii) To utilize the PBL method in the context

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of computer programming, focusing on problem-solving as a core component of the curriculum; (iv) To assess students' progress by administering both pre-tests and post-tests, providing quantitative data on their improvement; and (v) To evaluate and compare the level of student engagement and participation in programming activities, comparing current cohorts with previous ones to gauge the effectiveness of the intervention.

These objectives were designed to explore how the PBL approach could enhance students' problem-solving skills, particularly in the context of computer programming, and to determine its impact on their overall learning outcomes.

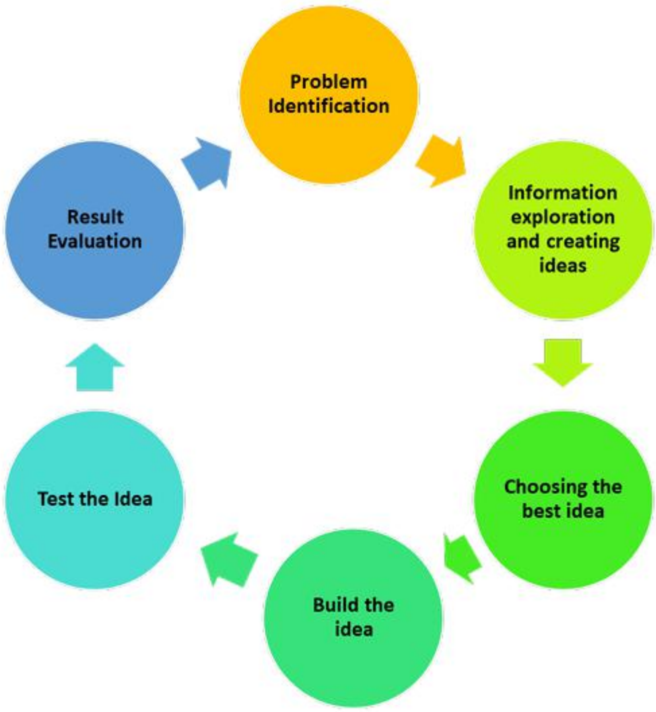

Figure 2: Problem Solving Loop[18]

6. METHODOLOGY :

A mixed research methodology was used in this study. The process of integrating qualitative and quantitative methods within a single study is known as mixed methods research. Mixed method designs are best suited for this research as here the studies are based on two main factors: priority and data collection implementation. Mixed methods researchers can prioritize quantitative and qualitative components equally, emphasize qualitative components more, or emphasize quantitative components more. There are various reasons why data collection focuses on one type of data over others, including the research question, practical limitations, and a need to comprehend one set of data before moving on to the next. Quantitative and qualitative data collection is implemented in a specific sequence in the research [13]. The purpose of survey research is to gather information from a sample of individuals by asking questions [14]. In this research, utilizing a variety of methods for recruiting participants, collecting data, and instrumenting their study. In survey research, quantitative strategies can be used

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(e.g., questionnaires with numerical ratings), qualitative strategies can be used (e.g., open-ended questions), or both strategies are being used (i.e., mixed methods) [15].

The study was conducted among 19 students and 10 tutors in the context of engineering education. A self-administered questionnaire survey was employed to collect data from students and tutors, aiming to understand their experiences in teaching and learning programming modules. Quantitative data was gathered through pre-tests, post-tests, examination results, and similar methods. In addition, data was collected through informal class discussions, group activities, and in-class assessments. Each participant signed a consent form to indicate their agreement to participate in the study.

7. FINDINGS AND EVALUATION:

The evaluation of the action research is conducted through a combination of tutors' reflections and a quantitative comparison of students' grades on assignments from the previous semester. Tutors' reflections, along with students' responses, are summarized and presented in Table 1 for further analysis.

Tutors' reflection	Students' response
All tutors highlighted that problem-solving in programming poses a significant challenge for students.	Sixty-nine percent of students reported that they understood Problem Solving in Computer Programming (PSCP) at an intermediate level.
Seventy-five percent of tutors believe that solving more programming problems will enhance students' Problem-Solving and Computer Programming (PSCP) skills, while 25% suggest that attending extra classes would help students improve their PSCP abilities.	Thirty-seven percent of students expressed a desire to take additional PSCP classes to enhance their programming abilities, while 32% preferred solving more tasks to improve their PSCP skills.
Eighty-three percent of tutors identified extra classroom practice as the most effective resource for improving PSCP skills.	Seventy-four percent of students indicated that they wanted additional classes to practice programming problem-solving.
Determining the logic for a given programming problem was identified as the most challenging aspect by 83% of respondents.	Fifty-nine percent of students reported struggling to determine the correct logic for programming problems.
Some tutors argue that the PBL strategy can enhance learners' problem-solving and programming abilities.	

Table 1: FINDINGS FROM THE SURVEY

The evaluation process involves a combination of both qualitative and quantitative data to assess the effectiveness of the intervention. Key data points include observations of group activities, class assignments, and formative assessments, which provide insight into student engagement and progress. Pretest and post-test results are used to measure changes in student knowledge and skills over the course of the intervention. Additionally, feedback from both students and tutors is gathered to evaluate the impact of the PBL approach on motivation, problem-solving abilities, and overall learning experiences.

Interviews with students and tutors, along with module surveys, further contribute to a more in-depth understanding of the intervention's effectiveness. These qualitative measures allow for a deeper exploration of how the PBL method influences student engagement and problem-solving skills. By

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combining these diverse evaluation methods, the study offers a well-rounded assessment of the action research's impact on student learning, performance, and overall development in programming.

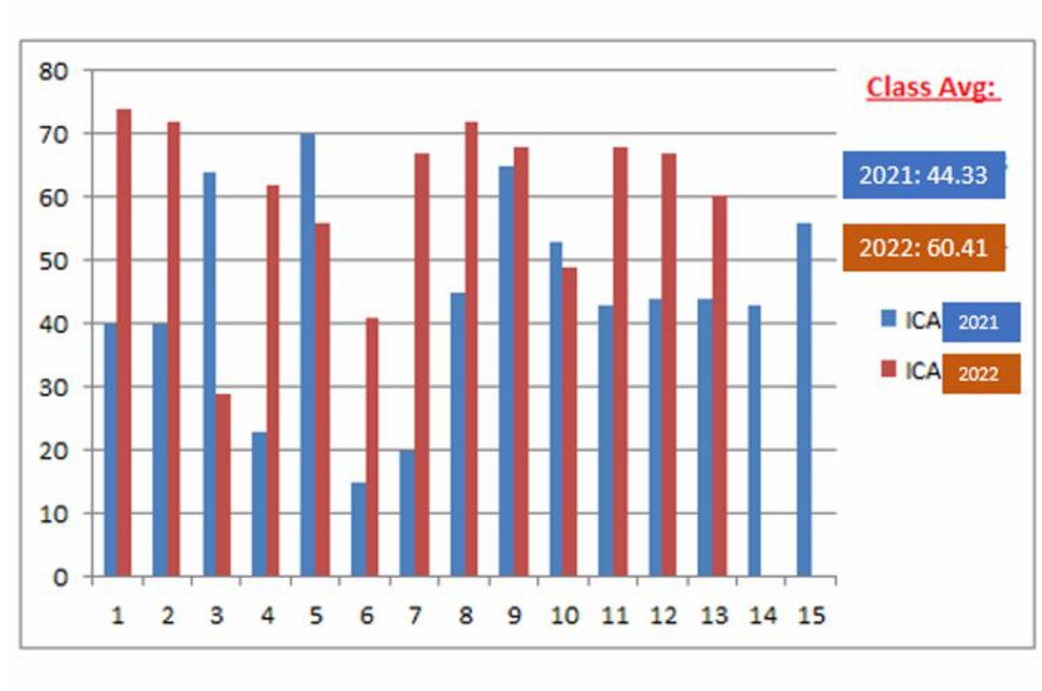

Figure 3: Summative Assessment

Pre-tests and post-tests were administered at the beginning and end of the intervention class to assess student progress. The responses to each question from every participant were recorded and analyzed for comparison. The results are presented in Figures 4 and 5, which visually depict the differences in student performance before and after the intervention. This comparison provides insight into the effectiveness of the intervention in improving student understanding and skills.

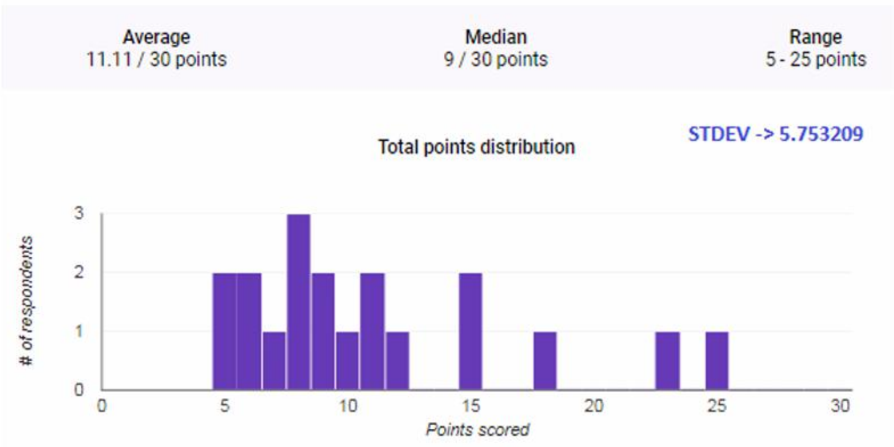

Figure 4: Pre-test Result: Number of participants-19

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Figure 4 displays the results of the pre-test, with the average score being 11.11. This initial score reflects the students' baseline understanding and performance in the subject before the intervention. The data serves as a starting point for assessing the impact of the Problem-Based Learning (PBL) approach on their progress throughout the intervention class.

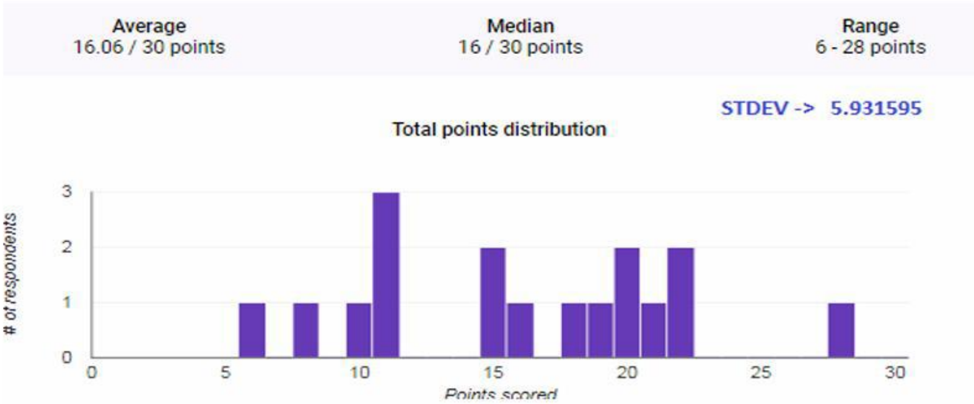

Figure 5: Post-test Result: Number of participants-17

A post-test was administered to the same group of students, as shown in Figure 5. The results from both the pre-test and post-test graphs clearly indicate a significant improvement in student performance following the implementation of the Problem-Based Learning (PBL) approach. In addition to the academic performance improvements, students also demonstrated a heightened interest in programming after engaging with the PBL method. Based on student feedback, it is clear that the PBL cycle, which involved collaborative group work and hands-on activities during the intervention classes, played a crucial role in enhancing their Problem Solving and Computer Programming (PSCP) skills. Furthermore, a comparison of the current cohort’s summative assessment (ICA) marks for the "Introduction to Programming" module with those of the previous cohort (Figure 3) reveals an improvement, further highlighting the positive impact of the PBL approach on student learning outcomes.

8. CONCLUSION:

Many novice learners face significant challenges in developing Problem-Solving and Computer Programming (PSCP) skills, often resulting in high failure rates and instances of plagiarism in programming modules. This study examined an action research project conducted during the academic year 2021-22, focusing on Level 4 computing students. To address these challenges, a Problem-Based Learning (PBL) approach was introduced in intervention classes, where students participated in a variety of structured activities aimed at improving their problem-solving and programming abilities.

The evaluation of student performance was carried out using a combination of methods, including surveys, student feedback, classroom activities, and both formative and summative assessments. The results clearly indicate that the PBL approach had a positive impact on enhancing students’ PSCP skills. By engaging students in problem-solving tasks and fostering critical thinking, the intervention helped them gain confidence and improve their overall programming proficiency.It is important to note that the findings of this study are context-specific and limited to the group of Level 4 computing students

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involved in the research. The results cannot be generalized to other departments, universities, or broader populations without further study. However, the success of the PBL approach in this context suggests that it has the potential to be effective in other learning environments. Future research could explore the application of PBL strategies on a larger scale, encompassing different academic levels, disciplines, and institutions, to validate and expand upon these findings.

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Effective Methods in Removal of Ocular Artifacts from EEG Signal

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Abstract: *The brain signal is an EEG, usually accompanied by a lot of noise and artifacts which should also be removed and redefined to obtain faithful brain signals. Applying electrical activities of the brain to three performance methods, which are Fast Independent Component Analysis (FastICA),Principal Component Analysis (PCA) and wavelet transform to extract unobserved neural activities and ocular artifacts(OA) such as eye blinks, eye movements etc. Evaluation and contrast of these techniques were based on their ability to extract relevant neural information, suppress noise, and interpret physiological signals. The comparison highlights how the different methods processed EEG signals. Based on the metrics values wavelet transform is more effective in reducing ocular artifacts and separating sources. The choice of method based on the desired outcome of the EEG analysis and primarily focuses to minimize noise or to preserve the original brain activity signal.*

Key Words: *Electroencephalography (EEG), Ocular artefacts (OA), Fast Independent Component Analysis (FastICA), Principal Component Analysis (PCA) , wavelet transform.*

1. INTRODUCTION:

EEG or Electroencephalography is a technique through which time-dependent electrical activity of the brain can be recorded by attaching electrodes to the scalp of the subject. EEG has various advantages over other imaging techniques like FMRI and PET because the latter two control centres involve bulky equipment, often located within the hospital, While EEG is easy to obtain, is painless, and portable, in order to place a value on most of them, particularly in the evaluation of seizures or dementia. EEG signal is usually subdivided to five ranges, i.e delta, theta, alpha, beta and gamma, [2] which are measured at frequencies averaging from 0.1 Hz to more than 100 Hz.

Frequency Band	Speed(Hz)	Mental State	EEG recording(1sec)
Delta	1-4	Deep sleep	
Theta	4-8	Drowsy	
Alpha	8-12	Relaxed	
Beta	12-30	Focused	

Table: 1.1 The Frequency Bands of EEG Signals

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The amplitude of the EEG signal is in micro volts and is very vulnerable to interference from disturbance called "artifacts." These artifacts distort the important neural information required for analysis. The contamination happens at both the frequency and time domains of the EEG signal, thereby making it tough for clinicians to diagnose neurological disorders accurately without an apparent and artifact-free EEG. Internal factors could be derived from physiological activities such as eye blinks and body movements or even heartbeats. The artifacts may also come from the outside such as environmental noise, interference by the instruments, or even shifting of cables and electrodes. Only a few types and sources of Artifact are illustrated in Table 1.2

Artifact	Type	Source
Eye blink	Ocular	Internal/Physiological
Eye movement	Ocular	Internal/Physiological
REM Sleep	Ocular	Internal/Physiological

Table: 2.1 Types of ocular artefacts

Pre-processing of EEG signal is necessary as it helps in the detection of OAs. The removal of these artifacts significantly distorts the neural signals, and giving incorrect analysis and interpretation. That is why pre-processing of EEG signal is required. Some of the advantages of pre-processing are improve signal clarity, enhances diagnostic accuracy and preserves neural Information

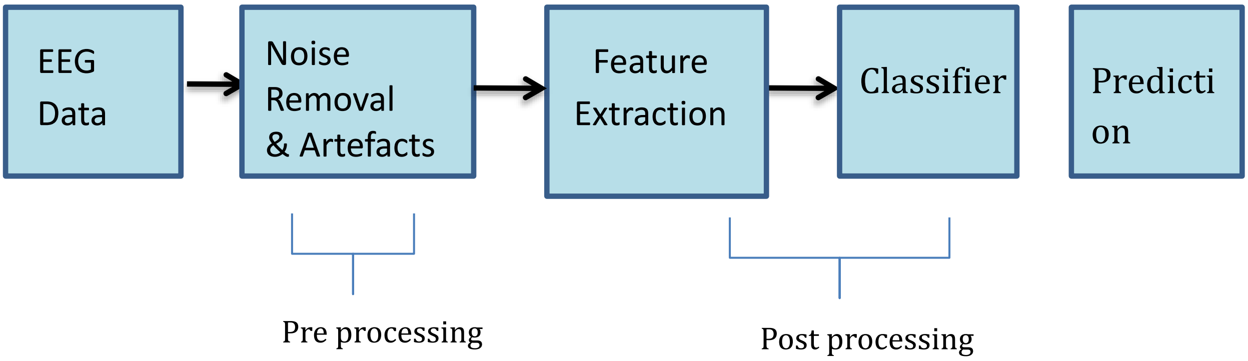

Fig: 1.1 General Block Diagram

2. LITERATURE REVIEW:

[1] **Erkan, E** et.al proposes a method combining Independent Component Analysis (ICA) and Wavelet Transform, for ocular artefact removal from EEG signals without requiring reference signals. The technique identifies the regions of ocular artefact in the time domain, decomposes the signal by ICA, and selectively applies wavelet transform on the components carrying the artefacts. By zeroing out the wavelet coefficients corresponding to the artefact regions and reconstructing the signal, the artefact removal from EEG signals effectively preserves the neural information. Results on real data demonstrate that this approach outperforms the traditional ICA-based zeroing techniques, which preserve the signal integrity but remove artifacts.

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[2] İ. Kaya et.al explains the awareness among EEG researchers regarding the existence of artifact management tools and preprocessing pipelines, thereby enhancing signal clarity and, consequently, research outcomes. Major challenges in the use of EEG arise due to artifacts; indeed, although unavoidable internal (occurring within the skull, such as ocular or muscular) and external disturbances commonly complicate signal analysis. Internal artifacts are challenging because they overlap with neural information, while effective artifact management is critical for resting-state as well as ERP studies.

[3] Islam MK et.al Artifact presence in EEG recordings is the reason for developing practical methods for its detection and removal. This review outlines state-of-the-art procedures on the treatment of scalp EEG artifacts, discussing their advantages and disadvantages, as well as application- dependent suitability. Furthermore, this article explains some types of artifacts and their effects on EEG based applications. Although no performance assessment is conducted, functional comparison and future challenges in this field are discussed. It is a comprehensive guide for researchers to develop, refine, or apply artifact handling techniques.

[4] Liu, J et.al introduces a new artifact removal method that uses ICA and Wavelet Transform without needing reference signals. The new approach identifies the regions in the time domain where the ocular artifacts are and then applies ICA on the signal decomposition. Selective application of Wavelet Transform on artifact-containing components is then applied. The method effectively preserves neural information by zeroing artifact-related wavelet coefficients and reconstructing the signal. In tests performed on real data, this method outperforms traditional ICA-based techniques while preserving signal integrity and removing artifacts.

[5] G. Wang, C introduces an ICA-based MEMD method that removes electrooculography artifacts from multichannel EEG signals. MEMD decomposes EEG signals into multivariate intrinsic mode functions, and then EOG-related components are identified and reconstructed. Finally, ICA is used to isolate EOG-linked independent components followed by the reconstruction of a signal through inverse ICA and MEMD. Tests on simulated and real data demonstrate that the proposed method efficiently removes EOG artifacts without losing any information. It significantly enhances signal-to-noise ratio and minimizes mean square error in comparison with existing method.

[6] Hamal A Q EEG signal pre-processing with respect to artifact and its removal are discussed here, which will focus on traditional single-stage as well as multistage techniques and their strengths and weaknesses. Single-channel methods require less computation but less effectiveness regarding the removal of complex artifacts; hybrid techniques improve the performance but at the cost of increased time complexity. Efficient handling of a multiple artifact demands a balance between performance, computational efficiency, and time. The paper also provides an overview of available datasets and trends in EEG processing with the aim of guiding researchers in refining artifact-handling methods and reducing the burden on experts.

3. OBJECTIVES / AIMS:

The aim of this paper is to discuss ocular artifacts in EEG signals and explore effective methods for their elimination. The study evaluates and compares the performance of three artifact removal techniques—Fast Independent Component Analysis (FastICA), Principal Component Analysis (PCA),Wavelet Transform method .The analysis has done on the basis of key metrics such as Signal-to-Noise Ratio (SNR), Mean Squared Error (MSE), and Power Spectral Density (PSD) using available EEG datasets.

ISBN: 978-81-976827-5-9

4. RESEARCH METHOD :

Various approaches have been used to detect and remove ocular artifact in EEG signal in time, frequency and time- frequency domains. PCA, FastICA, Wavelet Transform, Empirical mode detection, Event related potential etc... The time-domain features include mean, variance, and skewness, that contain simple statistical information. Power spectral density (PSD) and Fourier Transform are the features used in frequency-domain techniques that based on the frequency components of the EEG signal. The time-frequency domain combine the information from both sources and give a bigger overview, like Wavelet Transform, STFT etc…These methods come with their limitations. For example pathological signals may sometimes overlap during seizure activity. So it is difficult to identify this during seizure activity. Some methods may remove relevant information from EEG which makes real-time application challenging.

To address these limitations based on matrices obtained Wavelet Transform is proposed. The performance of each technique is evaluated using metrics such as Signal-to-Noise Ratio (SNR), Mean Squared Error (MSE), and Power Spectral Density (PSD) on available EEG datasets.

Artifact Detection Methods

Based on the time, frequency and time- frequency domain features many approaches have been used to detect and remove ocular artifact in EEG signal .The methods taken for analysis are explained below.

Fast Independent Component Analysis (FastICA)

Fast Independent Component Analysis is a sophisticated computational refinement of ICA, designed to efficiently isolate mixed signals into statistically independent components; it has the property that every component is an individual source signal. FastICA has high speed and reliability with various applications in signal processing, neuroscience, and finance among other disciplines, especially for functions like artifact removal, feature extraction, and blind source separation. Combining FastICA with methodologies like wavelets increases its power in the task of special processing, such as enhancing EEG signal processing.

Let P be the observed mixed signal, and Q be the source signals which is to be recover. Fast ICA aims to solve the equation

$$P=R.Q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where R is the mixing matrix. Fast ICA estimates Q and R by preprocessing P and

$$\text{Whitened } P'=U\cdot P\ldots\ldots\ldots\ldots (2)$$

Where U is the whitening matrix. Optimizing the weight vector w: The algorithm normalizes after each step to ensure convergence .Extracting Independent Components:

$$Q=W\cdot P \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where W is the weight matrix containing optimized weight vectors.

Principal Component Analysis (PCA)

PCA is one of the commonly applied statistical methods for dimensionality reduction in dimension, feature extraction, and visualizing a multivariate data set. Reduce number of variables, without losing the variation found in original data; save information by preserving maximum variability.

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This is very helpful in reducing high-dimensional data and overcoming the "curse of dimensionality. "PCA discovers patterns in the data based on variance. It reduces redundancy due to correlations among variables. The principal components are orthogonal to each other, meaning that each one picks up different features of the data.

For a given a dataset X with R observations and P variables: Mean-centered data matrix A can be calculated by

$$A=B-\bar{B}\text{…………………(4)}$$

Covariance matrix M can be calculated by $\frac{1}{n-1}A.A^T$……...(5)

Eigen values Y and Eigen vectors Z are calculated by using the equation

$$MZ=YZ\text{…………………..(6)}$$

Select the k largest eigenvalues and their corresponding eigenvectors to define the principal components. Project the original data onto the principal components:

$$D=AV_k\text{………………...(7)}$$

Where V_k is the matrix of the top k eigenvectors.

Wavelet Transform

The Wavelet Transform offers a versatile tool for analysis of signals, with benefits of both time and frequency localization, unlike the Fourier Transform. It is ideal for analyzing non-stationary signals like EEG, for which the frequency content may change over time. Waves can be scaled and shifted to examine different resolutions because wavelets are small finite-duration wave-like functions. This multi resolution approach allows for the detection of transient features, such as spikes or artifacts, and permits simultaneous analysis of coarse and fine details, making it very useful in EEG signal processing for identifying distinct brain activities across frequency bands.

The signal is passed through a pair of filters and the filtered outputs are down sampled to reduce redundancy. The original signal can be reconstructed using inverse wavelet transform by up sampling and combining the filtered components. The choice of wavelet function depends on the application and characteristics of the signal.
The wavelet transform of a signal f(t) is given by

$$T(a,b)=\int_{-\infty}^{\infty} f(t)\psi_{a,b}(t)dt \quad\text{……..(8)}$$

Where $\Psi a,b(t)$ is the shifted version of wavelet function.

Performance Evaluation Metrics:

(i) Signal-to-Noise Ratio (SNR): Measures the quality of the signal after artifact removal.

(ii) Mean Squared Error (MSE): Measures the deviation of the reconstructed signal from the original clean signal.

(iii) Power Spectral Density (PSD): Evaluates the preservation of relevant of frequency components in the processed signal.

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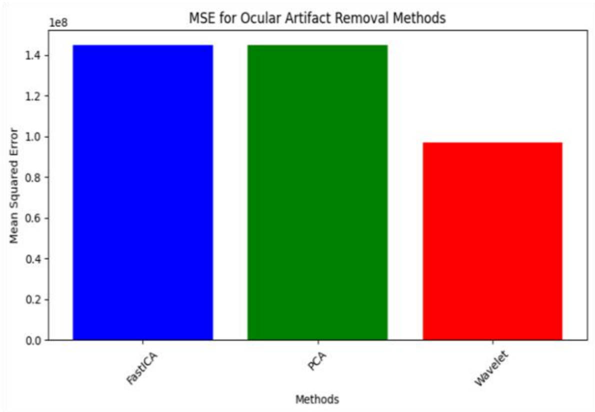
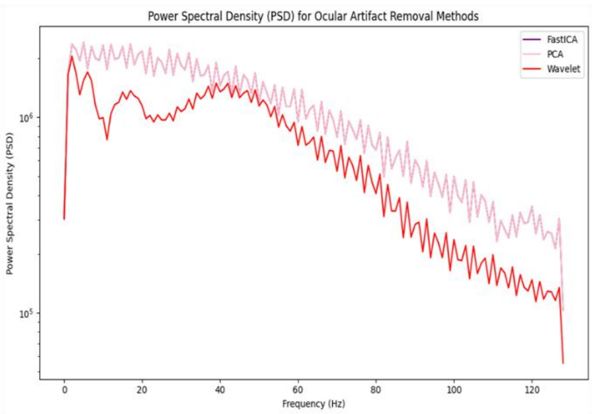
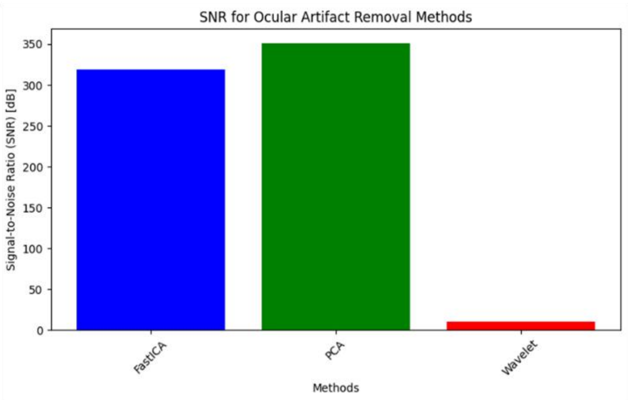
Experimental Procedure:

(i) Process EEG channel using all three methods.
(ii) Metrics are used to measure the performance of each method.
(iii) Compare results for channels and calculate metrics across all channels.
(iv) Determine which method provides the best balance between artifact removal.
(v) Plot the SNR, MSE, and PSD values for each method.

5. RESULT / FINDINGS :







Metric	FastICA	PCA	Wavelet
MSE	144938402.1633632	144938402.16336316	97175378.51003766
SNR	319.373002694119	351.0903916246657	10.262678759731026
PSD	306735.6995023, 1664654.64207875	306735.6995023, 1664654.64207875	301939.00491804 1642557.49570125

Table 5.1: Comparison of Artifact Removal Methods Based on MSE, PSD, and SNR Metrics

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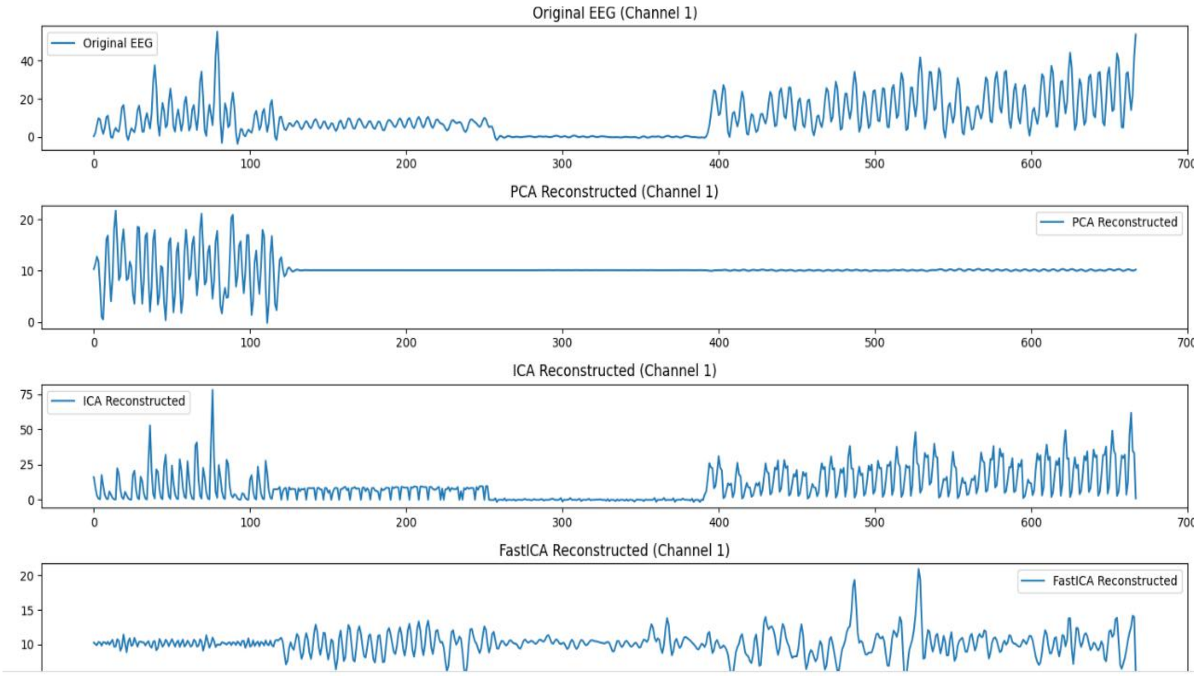

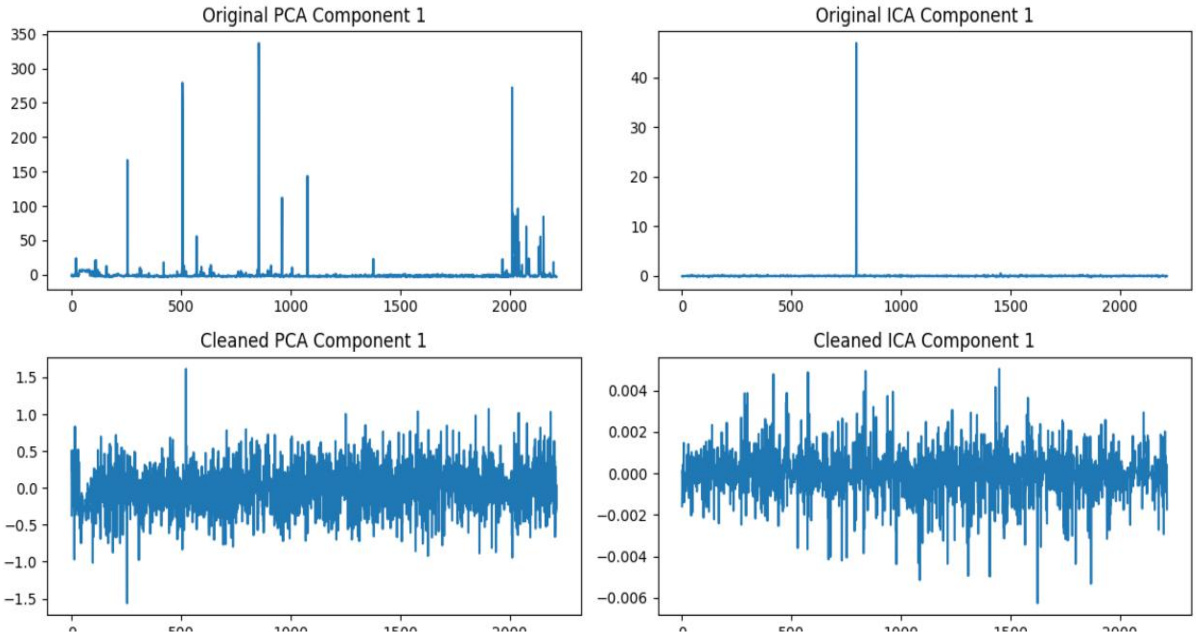

6. DISCUSSION / ANALYSIS:

Wavelet has the lowest MSE (97,175,378.51), suggesting it introduces the least distortion during artifact removal. FastICA and PCA have higher PSD values compared to Wavelet. This suggests that FastICA and PCA retain more power from the signal. PCA has the highest SNR (351.09), followed by FastICA (319.37), while Wavelet has a very low SNR (10.26). This suggests PCA is the most effective in preserving the signal while reducing noise. Significant improvements in SNR and lower MSE values observed.

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7. CONCLUSION :

Artifact removal methods differ in performance based on performance criteria. The lowest MSE is obtained in Wavelet Transform, but the distortion introduced is at its minimum, thus very useful for preserving signal integrity. FastICA and PCA have retained more signal power, as indicated by their PSD values. The best noise reduction with preserved signal is achieved by PCA due to its highest SNR. FastICA is followed. Although Wavelet has the lowest SNR, it shows minimal distortion. In balancing noise attenuation, signal preservation, and computational requirements, the choice of method is determined.

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Predicting Diabetes Using Advanced Quantum Machine Learning Algorithms

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Abstract: *Diabetes mellitus (DM) is a pervasive chronic condition with significant global health implications. Traditional machine learning methods have been employed to predict diabetes, but recent advances in quantum computing offer new opportunities to enhance predictive accuracy and efficiency. This study investigates the application of advanced quantum machine learning algorithms for the prediction of diabetes. By addressing existing research gaps related to scalability, integration with classical models, interpretability, and practical application, this research aims to develop hybrid models that leverage the strengths of both quantum and classical computing. The outcomes will provide a comprehensive framework for improving diabetes prediction models, Contribution to better medical diagnostics and patient care.*

Key Words: *Diabetes Prediction, Ensembling Classifier, Machine Learning, Multilayer Perceptron, Missing Values and Outliers, Dataset.*

1. INTRODUCTION:

Diabetes mellitus (DM), commonly known as diabetes, is a metabolic disorder characterized by elevated blood sugar levels. Insulin, a hormone, typically facilitates the transfer of sugar from the blood to the cells for energy. In individuals with diabetes, the body either produces insufficient insulin or cannot effectively utilize the insulin it produces, resulting in high blood sugar levels. Prolonged elevated blood sugar levels can lead to damage to the nerves, eyes, kidneys, and other organs. The prevalence of diabetes has increased significantly from 108 million in 1980 to 422 million in 2014. This increase is more rapid in developing economies than in developed nations. However, the probability of death between the ages of 30 and 70 from major non-communicable diseases (including cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes) decreased globally by 22% from 2000 to 2019. Healthcare costs are rapidly increasing to mitigate complications and enhance the quality of life of patients with type 2 diabetes mellitus. Research has shown that controlling glycaemic levels can help prevent organ damage and other diabetes-related complications. In some cases, blood sugar levels in patients with type 2 diabetes can be reduced, potentially decreasing disease progression and the associated risk factors. Numerous studies have developed models using machine and deep learning to accurately predict type 2 diabetes mellitus in patients. Traditional binary computer approaches have demonstrated uncertainty and inaccuracies in predictions. This study focuses on the need for Quantum Computing Algorithms, comparing Quantum Processing Units (QPUs) with classical binary approaches. It applies and compares Quantum Machine Learning (QML) and Machine Learning (ML) algorithms such as KPCA, SVM, Decision Tree, and Bayesian Network to diabetes datasets. This study evaluated the accuracy and performance of these algorithms against those of traditional machine learning classifiers. The remainder of this paper is structured as follows: Section I introduces QML, ML, and Diabetes; Section II discusses the case status data and predictive variables in the dataset; Section III presents quantum and classical machine learning algorithms; Section IV outlines the

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experimental framework and analysis of the results; Section V compares quantum and classical algorithms; and Section VI concludes the paper.

2. LITERATURE REVIEW:

Author	Method/Approach	Title, Journal & Year	Findings
BBNS. Prakash, B. Naveen, MD. Akhiluzzama, Pothuraju Rajarajeswari	Kernel Principal Component Analysis Decision Tree Support Vector Machine Bayesian Network Q Boost Classifier	Comparative Performance Analysis of Quantum Algorithm with Machine learning Algorithms on Diabetes Mellitus IEEE (2023)	the predicted model developed using mat-plot library and seaborn library which showing the accuracy, sensitivity, F1-score and specificity of the classifiers The Quantum Processing Unit(QPU) run time of the QBoost, Enhance Model 1 and Enhance Model 2 as 0.0428, 0.379 and 0.328sec respectively, from this prediction the quantum model is ~57 times rapid compared to dassical model. To ensure Security it is very Robust and reliability in nature. The results of the predictions. They're shown pictorially in graph shows that the produced Quantum algorithm present better in terms of Accuracy (73.4%), Sensitivity(78.1%), F1-score(80.3%) and Specificity. (85.7%) compared to other classification algorithms.
Deepti Sisodia, Dilip Singh Sisodia	Model Diagram *Brief Description of Algorithms Used* *Support Vector Machine (SVM)* *Naive Bayes Classifier* *Dataset Used*	Prediction of Diabetes using Classification Algorithms ICCIDS 2018	One of the important real-world medical problems is the detection of diabetes at its early stage. In this study, systematic efforts are made in designing a system which results in the prediction of disease like diabetes. During this work, three machine learning classification algorithms are studied and evaluated on various measures. Experiments are performed on Pima Indians Diabetes Database. Experimental results determine the adequacy of the designed system with an achieved accuracy of 76.30 % using the Naive Bayes classification algorithm. In future, the designed system with the used machine learning classification algorithms can be used to predict or diagnose other diseases. The work can be extended and improved for the automation of diabetes analysis including some other machine learning algorithms.
Pedregosa, Varoquaux, Gramfort et al. Matthieu	*Numpy* *Scipy* *Cython* *Objects specified by*	Scikit-learn: Machine Learning in Python csie2012	*Scikit-learn* exposes a wide variety of machine learning algorithms, both supervised and unsupervised, using a consistent, task-oriented interface, thus enabling easy comparison of methods for a given application. Since it relies on the

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Brucher Matthieu Perrot	*interface, not by inheritance*		scientific Python ecosystem, it can easily be integrated into applications outside the traditional range of statistical data analysis. Importantly, the algorithms, implemented in a high-level language, can be used as building blocks for approaches specific to a use case, for example, in medical imaging (Michel et al., 2011). Future work includes *online* learning, to scale to large data sets.
Mohd Hammem Sharief, Mohammed Imran, Mohammed Saqeeb, Saleha Butool	Support Vector Machines (SVM) parameterized quantum circuit (PQC)	COMPARATIVE PERFORMANCE ANALYSIS OF QUANTUM ALGORITHM WITH MACHINE LEARNING ALGORITHMS ON DIABETES MELLITUS IJESR. 2024	Therefore, from the comparative performance analysis of quantum algorithms with machine learning algorithms on diabetes mellitus, it can be concluded that while quantum algorithms show promising potential for certain aspects of healthcare analytics, such as optimization and pattern recognition, their current practical implementation and performance still require significant advancements to surpass classical machine learning algorithms in terms of accuracy and efficiency for tasks like diabetes mellitus prediction. Machine learning algorithms, particularly those like support vector machines, continue to demonstrate robustness and reliability in handling medical data, offering effective tools for predictive modeling and decision support in healthcare settings. Future research should focus on refining quantum algorithms, improving their scalability and accuracy, to harness their theoretical advantages more effectively in practical healthcare applications.
Himanshu Gupta· Hirdesh Varshney· Tarun Kumar Sharma· Nikhil Pachauri · Om Prakash Verma	deep learning (DL) and quantum machine learning (QML) techniques	Comparative performance analysis of quantum machine learning with deep learning for diabetes prediction	In the proposed work, the diabetes prediction model has been accomplished by employing QML and DL framework. The importance of preprocessing and EDA has been explored and it has been found that they play an important role in robust and precise prediction. Further, the optimum number of layers have been obtained for both QML and DL models. The results obtained by utilizing optimum QML and DL models have been compared against the state-ofthe-art models and the comparative analysis reveals that the

ISBN: 978-81-976827-5-9

			developed DL model outperformed all the other models. Therefore, the developed DL model has shown great potential for the prediction of diabetes from PIDD. Further, although the performance of employed QML is still struggling as compared to the proposed DL but, compared with the existing models. In the future, the developed DL model will be examined on other diabetes datasets to examine the robustness of the model and a user-friendly web application will be developed. Moreover, the proposed QML model needs to integrate with the deep learning framework which may boost the performance against the developed models and state-of-the-art techniques.

3. RESEARCH METHOD :

Dataset

In the literature, a number of public datasets for the prediction and classification of diabetes are available. However, it has been found that the mortality rate of diabetes is higher in women than in men because the deaths associated with diabetes in 2019 were 2.3 million and 1.9 million, respectively. Furthermore, most of today's world population relies greatly on processed foods with less physical activity. Therefore, to investigate the risk of diabetes among females, PIDD (developed by the National Institute of Diabetes and Digestive and Kidney Diseases) was used in this study. This dataset is versatile and reliable for diabetes prediction. The PIDD contains a total of 768 instances of females aged above 21 years, of which 500 samples were non-diabetic (negative), and 268 patients had diabetes (positive). PIDD has been extensively utilized to predict the possibility of diabetes for any particular observation based on the eight most influential independent features: pregnancy (P), glucose (G), blood pressure (BP), skin thickness (ST), insulin (I), body mass index (BMI), diabetes pedigree function (DPF), and age. Descriptions of these features with a brief statistical analysis of the PIDD are presented in Table 1. Further, based on class-specific density distribution, these features are illustrated in Fig. 2 for a better understanding of the dataset.

Quantum Computing

Quantum computing (QC) is a fusion of Quantum Mechanics and Quantum Information. Quantum Information contains the state of the QC. QC has properties of Quantum Mechanics, such as Superposition, Entanglement and Tunneling. Quantum Information algorithms are used within ML and artificial intelligence in quantum systems. QML aims to comply with quantum algorithms to perform ML tasks. QML revolutionizes speed and performance.

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Quantum Computing Model

QBoost Classifier: QBoost is an ensemble learning method that uses Quantum Annealing (QA). In order to use the maximum power of DWave QA, preparation of the objective function with reference to QUBO is required. To achieve this, we altered AdaBoost by substituting the standard weighted error function with QUBO.

$$w* = \arg\min_{w} \left(\sum_{s} \left(\frac{1}{N} \sum_{n}^{N} w_n c_n(x_s) - y_s \right)^2 \right) + \lambda ||w||_0$$

where C(x) is a strong classifier that assembles repeatedly. In each repetition, chooses a weak classifier and relearns to reduce the weighted error function. Their weights were modified and renormalized to ensure that the sum of all weights was equal to one. The first part illustrates the distinction between weak and correct labels. The second part illustrates the degree of weakness of the classifiers used in the final classifier. is a regularization variable that adapts to the number of weak classifiers, which concerns the total Hamiltonian. There is a requirement to maximize this Hamiltonian by acknowledging the first part as the cost of the objective function, and the second part as a constraint. Reducing with QA allows us to acquire an amalgamation of weak classifiers that best fit the training data.

4. RESULT / FINDINGS:

QC classifiers, such as Qboost Plus, New Model 1, and New Model 2, use all classical classifiers. Qboost plus consists of (Decision Tree, Random Forest, XGB and Adaboost), New Model 1 consists of (voting and Qboost), and similarly, New Model 2 comprises on (voting model 2 and Qboost) classifiers that build a new classifier that runs on the quantum system. Selecting the appropriate parameters to train the classifiers is considered the best approach for achieving better results. Ensemble learning involves preparing several weak predictors and combining the results of each of these predictors to obtain the final prediction result from Quantum state. The maximum depth of a binary tree is the number of nodes along the longest path from the root node down to the farthest leaf node, tuning the weights, no of estimators and the hyper parameters of weak and strong classifiers along with regularization of lambda () for Qboost in terms of constructing QUBO.

In order to analyse the behaviour of the classifiers the following metrics were used: accuracy, precision, recall, and specificity. Specificity is vital in medical disease classification and provides additional information on the classifier of the disease. The accuracies obtained for each classifier are presented.

The implemented model of our system was analysed by fetching the well-known standards of the confusion matrix, such as precision, recall, accuracy, f1-score, and specificity. The formulas for individual entities are as follows:

$$Precision = \frac{TP}{TP + FP}$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$F1 - Score = 2 * \frac{Precision * Recall}{Precision + Recall}$$

$$Recall = \frac{TP}{TP + FP}$$

$$Specificity = \frac{TN}{TN + FP} or \frac{TP}{FN + TP}$$

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5. CONCLUSION :

In this study, we proved that our approach towards the binary classification of the diabetes dataset using the new models is feasible and faster, when they runs on a quantum system. The new models are based on the ensemble learning by combining classical and Quantum algorithms to construct a new classifier that runs on the Quantum system. The obtained results are satisfactory with the accuracies of 69% and 68.38%, a Recall and F1-score are 69% and 68.38% for the binary classification in the Classical and the Quantum system. The voting system is important for better accuracy, but the classical system takes bit longer time than the quantum to classify our diabetes data. We conclude that even including more and more algorithms in the Voting system results remains the same. The Voting Model 1 and Voting Model 2 have the almost same accuracy but Voting Model 2 takes less computational time in comparison of voting model 1. we choose the voting model 2 have better computation time than the voting Model 1. Quantum algorithms like New Model 1 and New Model 2 promises the similar accuracy's, recall, F1 scores and reduces the computational time. QC will be a useful and faster system in real-time application. The future direction is to be train dataset with different algorithms like qSVM and multi-label classification with of our improved system.

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