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Editorial Note

American physicist Arthur Leonard Schawlow said, "To do successful research, you don't need to know everything, you just need to know one thing that isn't known". Research involves creating new knowledge or use the existing knowledge in a new and creative way so as to generate new concepts, methodologies and understandings. The world of research is constantly evolving. With the rapid development of technology and the increasing focus on interdisciplinary research, the future of research is filled with exciting opportunities and new directions. While new technologies may usher in vast improvements to our future, it is essential that we don't lose sight of the risks they may pose and take measures to mitigate them.

The objective of Technology and Future is to publish up-to-date high quality, original research papers and reviews. The journal also aims to disseminate new knowledge on recent technological advancement among academic and research community, professionals. The journal showcases research papers based on findings across the full range of engineering fields. The journal provides a platform for researchers, academicians and students to publish their research and developments in the field of engineering.

This issue features a series of innovative articles such as Small Modular Nuclear Reactors and their Role in Energy Transition, Enhanced Bitumen using Reclaimed Asphalt Aggregate and Styrene Butadiene Rubber in Dense Bituminous Macadam, Design and Fabrication of Remote-controlled Tilling, Weeding and Seeding Machine, Weight Governor, Implementation of an E – Kick Scooter, Vitalmedsync: AI-driven Workflow Automation and Personalized Patient Care, Advancing Game Development and Simulation with Unity 3D: Integration of Procedural Content Generation, Genetic Algorithms,and Immersive Learning Experiences, A Review on Air Flow and Air Drag Charging in Evs, Sounz : Social Platform for Music Collaboration, VR Chatbot with ChatGPT API Integration: Techniques and Trends.

We would like to take this opportunity to thank all the authors for submitting their papers to Technology and Future journal of Science and Technology and to the esteemed peer reviewers who ensured the articles were of the expected quality.

Editor

Chief Editor

SMALL MODULAR NUCLEAR REACTORS AND THEIR ROLE IN ENERGY TRANSITION

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ABSTRACT

Transition to power generation based on sustainable energy sources is necessary to eliminate the greenhouse gas emission from fossil fuel based thermal power stations. Solar and wind are the promising renewable options, but their intermittent and seasonal nature underscores the need for more reliable alternative energy sources. Nuclear energy is a viable alternative however there are many disadvantages with conventional large nuclear power stations. The advanced version, Small Modular Reactor (SMR) emerges as a viable option which will address many of the disadvantages of the conventional nuclear reactors. SMRs, with capacities ranging from 10 to 300 MWe, offer benefits such as reduced land requirements, enhanced safety features, and adaptability for diverse applications, including integration with renewable energy systems. Globally, countries like the USA, China, Canada and Russia are actively pursuing SMR technologies. In India, Bhabha Atomic Research Centre (BARC) and Nuclear Power Corporation of India Limited (NPCIL) are actively engaged in research towards developing SMRs. Bharat Small Reactor (BSR), a modified 220 MWe Pressurized Heavy Water Reactor (PHWR) designed for reduced land use and enhanced safety is considered for immediate implementation. The integration of SMRs into India's energy infrastructure aligns with the nation's goal of achieving net-zero emissions by 2070. Diverse designs of SMRs all over the world may be able to provide clean energy and play a key role in the energy transition.

Keywords: Reactor, Breeder, Small Modular Reactor , Energy, Power

I. INTRODUCTION

Global warming and associated issues are the biggest challenge humanity is facing in the 21st century. Emission of greenhouse gases such as Carbon dioxide while burning fossil fuel in thermal power stations are considered as the major contributor to global warming. In order to limit the temperature, rising below 2°C the greenhouse gas emission should be brought down, and net zero emission should be achieved. To achieve this there should be a transition in electricity generation technologies. In the energy transition scenario, coal fired thermal power plants should be progressively replaced. Renewable energy sources, such as solar and wind are considered as the alternatives. However, solar and wind cannot produce electricity continuously and the capacity factor is relatively low. Nuclear energy is a viable alternative which can generate electricity with minimum carbon dioxide emission and produce power continuously throughout the day irrespective of the time of the day and weather conditions. More than 420 nuclear reactors are being operated in the world today, in 30 countries, producing around 9 % of the total electricity generated. In India, 25 nuclear reactors are being operated, and the total installed capacity is 8780 MW, which is only 1.8 % of the total installed capacity but the energy produced is around 3.1 % [1]. Nuclear

power is an inevitable option for India and the world to minimise the effect of greenhouse gas emission. Multiple units of conventional large capacity nuclear power plants are being operated at nuclear parks. But they have several disadvantages to adopting them for the future. To overcome these disadvantages Small Modular nuclear Reactors are considered. The research and development of SMRs are being undertaken in India and all over the world. This paper discusses in detail about the main features of Small Modular nuclear Reactors, its advantages and the current status of development in India and abroad.

II.NEED FOR ENERGY TRANSITION [2]

Globally 60 % of the electricity generated is from fossil fuel based thermal power stations. In India, this figure is higher, and it is around 75%. Thermal power plants emit huge quantity of carbon dioxide which is one of the greenhouse gases. In order to limit the global temperature rise within 2°C, we have to become carbon neutral. Carbon neutral means the amount of carbon dioxide and other greenhouse gases released due to different human activities should be made equal to the carbon capture capacity of the plants, trees and other technologies in the world. In order to achieve net zero emission in addition to carbon capture the carbon release also should be limited. For this burning of fossil fuels should be avoided. For every unit of electricity (one kWh) produced from a thermal power station, around 0.9 kg of carbon dioxide is emitted. In India, around 4 million tonnes of carbon dioxide per day is released to atmosphere from coal fired thermal power station. In modern super thermal high temperature power stations, the efficiency is higher and the emission per unit energy is relatively low. So, to reduce carbon emission, coal fired thermal power stations have to be progressively abandoned, and alternative energy resources has to be identified and developed. Solar and wind are the alternatives projected. Another renewable energy source is hydro, but the potential is almost fully utilised in the country. New plants are possible only at remote areas which will lead to high transmission cost and submergence of large forest area. Solar is a promising alternative but is functional only during daytime and its contribution is zero, during peak hours of electricity demand. Power generation technology which will deliver power continuously throughout the day irrespective of the climatic condition is needed to replace the thermal power stations. Nuclear energy is considered as the viable alternative. Nuclear parks with multiple units of large nuclear power reactors are already installed in India and abroad. However, the technology has to be refined to enhance safety, economy and handy for all types of consumers.

III.CONVENTIONAL NUCLEAR REACTORS AND ITS DISADVANTAGES

A nuclear reactor is a closed vessel where sustained fission chain reaction is maintained. As a result of fission chain reaction, kinetic energy will be gained by fission fragments and neutrons. The bombardment of fission fragments and neutron with fuel matrices will heat the fuel pin/pellet. The heat from the fuel is transferred and transported to the heat exchanger or steam generators by means of the coolant under circulation. Steam generators will produce steam at high pressure and high temperature which will be used for driving the turbine. The nuclear reactors are classified into different categories based on the fuel, coolant and moderator used. The most common power generating nuclear reactor in the world is Pressurised Water Reactor (PWR), which uses enriched Uranium as fuel and light water as coolant and moderator. Moderator in a reactor reduces the speed of the neutrons released after fission and the low speed neutrons will increase the probability of fresh nuclear reaction. Natural Uranium contains

0.7 % of fissionable nuclear fuel U 235 and

99.3 % of fertile element U238. Natural Uranium is subjected to a process called enrichment and the percentage of fissile content is increased to 3 to 4 % for using as fuel in the PWR type of reactor. Selective removal of U238 from the natural Uranium will lead to enrichment. The Kudankulam power plant in India is basically PWR technology and the origin is from Russia.

Pressurised Heavy Water Reactors (PHWR) are natural Uranium fuelled reactors with heavy water as coolant and moderator. Heavy water is used as the coolant and moderator to ensure neutron economy. As the fuel used is natural Uranium which has only 0.7 % fissile U235 content and hence the neutron produced after fission should be preserved without absorption to sustain the chain reaction. India is mastered in PHWR or CANDU type of reactor technology. The PHWR technology in India was initially started with the support of Canada. When Canada withdrew support unilaterally based on the Pokhran nuclear explosion, Indian scientists took it as challenge and the PHWR technology was fully developed indigenously and is matured now. Twenty one PHWRs are in operation now and the reactor power capacity ranges from 220 MWe to 700 MWe. Fast Breeder Reactors operates at high neutron energy spectrum with high speed neutrons. Moderators or any moderating material is deliberately avoided in the Fast Reactors. When the nuclear reactor is operated at high neutron energy spectrum, the neutron yield per fission will be higher, hence extra neutrons are produced. These extra neutrons are allowed to be captured in the blanket material surrounding the core which will have fertile depleted U238 atoms. The extra neutrons are captured by fertile U238 atoms and become Plutonium. Fertile Uranium atom is converted into Plutonium, which is a manmade fissionable material or nuclear fuel. In fast breeder reactors the extra fuel produced will be higher than the fuel consumed, so the name breeder. The Fast Breeder Reactors in future will convert the large quantity U238 and Thorium 232 available in the country to nuclear fuel Pu 239 and U 233. In the Fast Breeder Reactor the power density is very high, so liquid metal sodium is used as the coolant. The Fast Breeder Test Reactor (FBTR) is in operation at IGCAR, Kalpakkam and the technology is fully demonstrated. The Prototype type Fast Breeder Reactor (PFBR) of 500 MWe capacity is being commissioned at Kalpakkam site.

The recent advanced designs of all the above type of conventional nuclear reactors are of power around 700 MWe or more. In a Country like India such a nuclear reactor is to be installed in multiple units at nuclear parks, like Kudankulam site, to meet the growing energy demand. However, there are many disadvantages and issues with all these types of nuclear reactors[3],[4]. The main disadvantages are:

- Huge land area required
- High construction time
- Need for large quantity of water for cooling which ill lead to thermal pollution
- High capital cost
- Inability to use as a captive power plant
- Low refuelling time
- Operate as base load stations and are not load following
- Difficulty in integrating with grid with renewable energy sources

To address these challenges scientists and engineers of all over the world evolve a new concept called Small Modular Reactor.Many countries including India is currently involved in research and development activities of SMR. There are many SMR concepts pursued by different countries.

IV. SMALL MODULAR REACTORS AND ITS ADVANTAGES

Small Modular Reactors are a promising technology advancement in the area of nuclear energy [3],[4]. The electrical power output of an SMR unit is relatively low and is in the range of 10 to 300 MWe. Components and subsystems of SMRs are manufactured in factories and brought to plant site for assembly which reduces construction time and installation cost. They have passive and inherent safety features. SMRs are designed to have negative feedback coefficients, and natural cooling system. Automatic safety actions are built in a design which does not need any human intervention. Additional barriers are provided to avoid leakage of radioactive material from the plant. Some SMR designs allow high refuelling time of the order of 10 years which will increase the overall availability of the plant. SMRs are designed for various applications such as captive power plants, for requirements in energy intensive industries, data centres, supplying power to remote areas where grid support is not available, hydrogen production and for desalination. The SMR components can be mass produced in factories enabling standardisation, stringent quality control and reducing the per unit manufacturing cost. They need only smaller footprints compared to conventional nuclear power stations. Underground, underwater and on ship installations of SMRs are also being considered. As the SMR design is compact the thermal inertia is relatively low. This helps in making SMR design, load following, that is adjust the power output according to the demand and making them truly matching with renewable power sources such as solar or wind. This design feature of SMRs make it easily adaptable to the grid and ensures grid stability. The generating capacity can be increased by adding a greater number of modules and hence they are scalable.

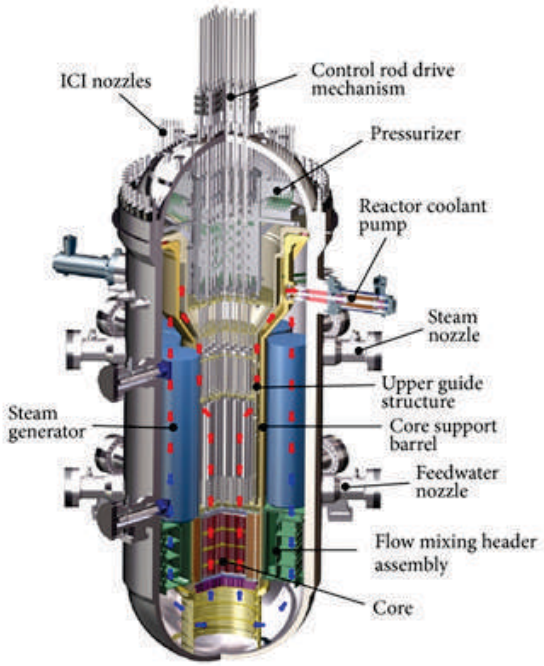

Fig. 1: A View of the SMR

V. RESEARCH ON SMRS AND STATUS OF DEVELOPMENT

During 2023 United Nations Climate Change Conference (COP28) in Dubai, United Arab Emirates, more than 20 countries pledged to triple global nuclear power capacity by 2050 [5]. PWR or LWR type SMRs, using normal water as coolant and moderator and enriched Uranium as fuel are the most common type of SMRs under development. NuScale power module and SMR-160 being developed by USA are examples. China is developing high temperature gas cooled SMR, HTR-PM. Molten salt reactors are liquid fuel reactors. Liquid fuel along with thorium is mixed with molten fluoride or chloride salts. During operation fertile thorium will get converted into fissile Uranium 233 and will act as a fuel subsequently. The IMSR reactor of Canada and ThorCon of Indonesia are examples of MSR. Sodium cooled Fast Reactors have the ability to recycle radioactive waste and

enhance sustainability. Gas cooled Fast Reactors which use Helium as coolant operate at high temperature and high efficiency, better fuel utilisation and have the potential of breeding. Countries such as US, Canada,China, Russia, UK and south Korea are in the field of SMR development and protype construction. Russia has already launched the first floating SMR by name Akadnik Lomsov for delivering power to remote areas since 2020. Four SMRs are under construction in US, Argentina, Russia and China. There are around 68 [5] types of SMR concepts which are under preliminary or detailed design stage. Microreactors are small SMRs of power capacity upto 30 MW(th). All conventional reactor coolants are considered for them. Microreactors are suitable for applications such as microgrids, remote areas, disaster recovery operations and critical service restoration. The diverse designs of SMRs which are being developed all over the world can provide clean, reliable and flexible energy which will contribute significantly towards global energy transition.

VI. SMR RESEARCH IN INDIA

India is planning to achieve net zero emission by 2070. To facilitate the shift towards clean and sustainable energy, India is actively considering nuclear power and SMRs. Bhabha Atomic Research Centre (BARC) and Nuclear Power Corporation of India (NPCIL) have already initiated the development of SMRs with the intention of integrating it to the national nuclear power implementation programme [2]. Our vast experience in PHWR is being effectively utilised for SMR design and development. India is also considering the development of molten salt reactor and lead cooled Fast Reactors which possess inherent safety features. However, the roll on of SMRs all over the world faces many challenges such as regulatory clearances, cost competi tiveness at the initial stage and public acceptance. India is also considering strategic partnership in this area with other leading nations such as Russia. In the recent union budget India has launched a comprehensive nuclear energy mission. An adequate amount of budget is dedicated to the development of SMRs and plan is to install at least five SMRs which are to be made operational by 2033. This is in line with India's ambitious goal of 100 GWe of nuclear power installed capacity by 2047. In order to ensure private participation in the area of nuclear energy government is planning to amend atomic energy act and Nuclear lability act. As SMRs technology progresses they are going to be play a crucial role in the successful sustainable energy transition in our country too.

VII.BHARAT SMALL REACTOR (BSR)

Bharat Small Reactor (BSR) design is based on the 220 MWe proven design of Indian PHWR. Safety and operating performance of these type of reactors are well proven and 16 of them are in operation now, in different parts of the country. By design BSR is not an SMR. The 220 MWe PHWR is modified by providing an additional inner steel lining on the outer containment wall to reduce the exclusion zone requirement and land requirement which make them suitable for installing very close to power intensive industries such as steel, aluminium, metal etc. as a captive power plant. The instrumentation system of the reactor is also replaced with state of art systems. These reactors are planned to be implemented within the existing legal frame work with capital investment, water supply and land provided by private parties and the entire design of the plant, quality control and operation and maintenance by NPCIL. An expression of interest bid from private parties to install BSRs are already invited by NPCIL.

VIII. CONCLUSION

Small Modular Reactors are a promising advancement in the field of Nuclear Engineering and Technology. They can

provide flexible reliable and safe nuclear power to the energy mix of various countries and to meet the net zero emission targets. They are cost effective, flexible and takes relatively low time of construction. India has also initiated research and development on various concepts of SMRs. Installation of Bharat Small Reactor an advanced version of 220 MWe PHWR is the immediate plan of India. SMRs are going to play a key role in energy transition in India and abroad.

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ENHANCED BITUMEN USING RECLAIMED ASPHALT AGGREGATE AND STYRENE BUTADIENE RUBBER IN DENSE BITUMINOUS MACADAM

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ABSTRACT

The increasing global demand for sustainable and cost-effective road construction necessitates innovative approaches to flexible pavement design. This study investigates the enhancement of Dense Bituminous Macadam (DBM) through the incorporation of Reclaimed Asphalt Pavement (RAP), Styrene-Butadiene Rubber (SBR) latex, and Waste Engine Oil (WEO). RAP provides a sustainable alternative to virgin aggregates, reducing material depletion and construction costs, while SBR latex and WEO improve the mechanical properties and longevity of the asphalt mix. Laboratory experiments were conducted to evaluate the effects of varying RAP, SBR, and WEO proportions on DBM performance. Key performance indicators, including Marshall Stability, flow values, and durability assessments, demonstrated significant improvements in structural integrity, resistance to rutting, and overall pavement flexibility. The findings highlight the feasibility of incorporating recycled and modified materials in asphalt mixtures to enhance sustainability while maintaining or improving pavement performance. This study supports the adoption of environmentally responsible construction methodologies, contributing to resource conservation and cost-effective infrastructure development.

Keywords: Dense Bituminous Macadam, Reclaimed Asphalt Pavement, Styrene-Butadiene Rubber, Waste Engine Oil, Sustainable Pavement, Asphalt Modification

I. INTRODUCTION

The development of resilient and sustainable road infrastructure has become an essential focus in modern civil engineering due to increasing environmental concerns, the depletion of natural resources, and rising construction costs. Dense Bituminous Macadam (DBM), a key material in flexible pavement construction, has traditionally relied on virgin aggregates and bitumen. However, the growing demand for cost-effective and eco-friendly alternatives has prompted the exploration of alternative materials. Reclaimed Asphalt Pavement (RAP) is one such alternative that offers significant benefits by recycling aged asphalt, reducing the need for new aggregates, and minimizing landfill waste. Incorporating RAP into DBM mixtures can significantly reduce environmental impact while maintaining pavement performance. Additionally, the use of polymer modifiers like Styrene-Butadiene Rubber (SBR) latex enhances the elasticity and durability of asphalt mixtures, which is essential for improving their resilience to temperature fluctuations and extending their service life in high-traffic areas.

In addition to RAP and SBR latex, the inclusion of Waste Engine Oil (WEO) as a bitumen rejuvenator presents a promising solution to enhance the properties of aged asphalt. WEO helps restore the original binder properties of aged asphalt, improving workability and ensuring the mixture remains durable and flexible. This combination of materials aims to balance sustainability and performance by optimizing DBM mixtures with

recycled and waste-based components. As the construction industry faces increasing pressure to utilize resources more efficiently, the integration of RAP, SBR latex, and WEO can offer a more sustainable and cost-effective approach to road construction without compromising the strength and longevity of pavements. The synergistic effects of these materials could pave the way for more environmentally responsible and economically feasible infrastructure solutions.

This study aims to evaluate the combined effects of RAP, SBR latex, and WEO on the mechanical properties of DBM, specifically focusing on its mechanical strength, rutting resistance, and fatigue performance. By analyzing these key factors, the research seeks to determine the optimal mix of materials that provide the best balance of sustainability, cost-efficiency, and long-term performance. A comparison of the physical properties of RAP and natural aggregates will be conducted to assess the effectiveness of RAP in enhancing DBM mixtures. Furthermore, the study will investigate the potential applications of enhanced DBM in addressing common road issues, such as potholes, which are a significant concern for infrastructure maintenance. Ultimately, this study aims to contribute to the development of more resilient and sustainable road infrastructure solutions, ensuring that future pavements are both high-performing and environmentally responsible.

II. LITERATURE REVIEW

The study in [1] on the partial replacement of aggregates with Reclaimed Asphalt Pavement (RAP) in Dense Bituminous Macadam (DBM) design for flexible pavements suggests that RAP materials, when blended with natural aggregates in the right proportions, can effectively meet the required grading standards outlined by MORTH specifications. Various tests conducted on the aggregates, including crushing tests, impact tests, and specific gravity tests, are crucial to ensure their suitability. For RAP, the Marshall test is conducted to assess its viability in flexible pavement base courses.

The benefits of using RAP in asphalt mixtures, particularly in enhancing rutting and fatigue resistance, have been widely recognized [2]. When RAP is reinforced with polymers, its load-bearing capacity improves significantly, outperforming unreinforced materials by 75.29% [3]. The properties of recycled aggregates tend to be more abrasive than normal aggregates, making it essential to evaluate their performance under stress conditions [3]. The addition of Styrene-Butadiene Rubber (SBR) at varying percentages (1%, 3%, and 5%) can improve the strength, flow, and stability of recycled asphalt aggregate mixtures, thereby fortifying their structural integrity [3].

SBR latex can enhance both the high- and low-temperature performance of emulsified asphalt mixtures [4]. SBR improves the adhesion properties of the mixtures, making them more durable in different environmental conditions. Additionally, studies have examined the role of waste engine oil (WEO) in improving the temperature sensitivity, flow, rutting resistance, and aging properties of asphalt. Combining WEO with SBR further improves the fatigue resistance and restores the viscous properties of asphalt, strengthening its ability to resist low-temperature cracking [5].

WEO serves as an effective rejuvenator for aged asphalt binders, restoring properties lost due to excessive aging [6]. This study emphasizes the importance of using WEO to enhance the rutting and fatigue resistance of flexible pavements. The authors of [7] focused on recycling methods for used engine oil, promoting its reuse over disposal to achieve substantial environmental benefits. Sorin Aurel and colleagues discussed global recycling technologies for waste engine oil, emphasizing their continuous improvement to

maximize recycled oil yield and recycling process efficiency [8]. Further reviews also highlight the versatile applications and benefits of RAP in pavement engineering, showing how RAP contributes to cost savings and sustainable construction practices [9], [10].

In conclusion, the combination of RAP, SBR latex, and WEO presents a sustainable approach to enhancing the properties of asphalt mixtures used in flexible pavements. As shown by various studies, these materials improve rutting resistance, fatigue performance, and overall durability. The integration of RAP with natural aggregates not only addresses environmental concerns of aggregate depletion but also provides a cost-effective alternative to traditional pavement materials. By incorporating SBR and WEO, the pavement's performance is further optimized, leading to longer-lasting and more resilient infrastructure. This paper contributes to the development of eco-friendly and efficient solutions in road construction, paving the way for more sustainable civil engineering practices.

III. METHODOLOGY

The methodology adopted comprised of both preliminary and experimental investigation. The materials required for the project are collected. Natural aggregates and RAP is collected from NHAI. SBR latex and Waste Engine Oil of required quantity is collected from the shop and workshop respectively. Preliminary tests which includes Specific gravity, Impact and crushing, Los Angeles abrasion tests were conducted on natural aggregate and RAP and then proper Mix design for DBM is selected. The collected aggregate properties to formulate mix designs for DBM Grade 2 according to relevant standards or specifications. Marshal specimen is prepared according to the mix design with incorporation of different proportion of SBR latex and waste engine oil. Test were conducted on prepared specimens for marshal stability and flow value. The test results were analyzed to determine the optimal bitumen content and the effects of addition of SBR latex and waste engine oil on mix performance

This paper presents the results of various tests conducted to evaluate the properties of RAP (Reclaimed Asphalt Pavement) and Aggregate. These tests assess key characteristics such as toughness, strength, density, and durability, which are crucial for determining their suitability in construction applications. The Aggregate Impact Test measures the resistance of aggregates to sudden impact, while the Crushing Value Test evaluates their ability to withstand compressive loads. The Specific Gravity Test provides insights into the density and porosity of the materials, influencing their stability and performance. Additionally, the Los Angeles Abrasion Test assesses the hardness and resistance to wear and tear. The results of these tests help in comparing RAP and Aggregate, providing valuable data for material selection in engineering projects. Table 1 shows that the test results of aggregate.

TABLE I. AGGREGATE TEST RESULTS

Tests	RAP	Aggregate
Impact Test	28%	29.85%
Crushing Value test	29.82%	28%
Specific Gravity	2.71	2.78
Los Angeles Abrasion Test	27.92%	29.38%

The impact value of natural aggregate & RAP is 29.85% & 28%, respectively, which is within the permissible limit of 30%. The natural aggregate & RAP Crushing Value is 29.82% & 28% respectively which is under the permissible limit of 40%. The natural aggregate and RAP Los Angeles Abrasion Value is 29.38% & 27.92 respectively which is under the permissible limit of 35%. The natural

aggregate and RAP Specific Gravity value is 2.71 & 2.65 respectively which is under the permissible limit of 2.6 to 2.9. Also Table 2 shows that the test conducted on Bitumen and modified bitumen.

TABLE II. BITUMEN TEST RESULTS

Tests	Normal Bitumen	Modified Bitumen
Softening Point	47.4 °c	52.4 °c
Viscosity	70 sec	90 sec
Ductility	86 cm	93cm
Flash And Fire Test	Flash=240 Fire= 320	Flash=270 Fire=360
Penetration Value	54	65

The viscosity values of normal and modified bitumen are 70 seconds and 90 seconds, respectively, falling within the acceptable range of 60–140 seconds. The ductility values are 86 cm for normal bitumen and 93 cm for modified bitumen, both exceeding the minimum requirement of 75 cm for pavement construction.

The flash and fire points for normal bitumen are 240°C and 320°C, while for modified bitumen, they are 270°C and 360°C. The softening points are 47.4°C for normal bitumen and 52.4°C for modified bitumen. The penetration values of normal and modified bitumen are 54 and 65, respectively, which fall within the permissible range of 40–70.

IV. EXPERIMENTAL INVESTIGATION

Preliminary tests on aggregate and bitumen were conducted, emphasizing the importance of this study. Furthermore, a detailed analysis was carried out using the Marshall test for mix design, which is explained in the next section.

V. MIX DESIGN

The sieve analysis is performed to determine the particle size distribution of aggregates by passing them through a series of standard sieves. This helps in assessing whether the aggregates meet the required gradation for Dense Bituminous Macadam (DBM). Individual gradation involves analyzing coarse aggregates, fine aggregates, and fillers separately to ensure proper particle size distribution. Blending for DBM is done by combining different aggregate fractions in specific proportions to achieve the desired gradation, ensuring strength, stability, and workability in the mix.

To design an optimal DBM mix, the optimum bitumen content (OBC) is determined by conducting trials with varying bitumen percentages to find the best balance of strength, durability, and workability. The optimum SBR and Waste Engine Oil content is similarly identified by blending them in different ratios to enhance the binder's flexibility, resistance to cracking, and performance. The Marshall Test is then conducted to evaluate the stability and flow properties of the asphalt mix, ensuring it meets structural and performance requirements before application in pavement construction.

VI. MARSHALL TEST

The Marshall Test is a widely recognized method for evaluating the stability and flow characteristics of bituminous mixtures. This test is particularly important in assessing the mechanical performance of Dense Bituminous Macadam (DBM) when modified with alternative materials such as Reclaimed Asphalt Pavement (RAP), Styrene-Butadiene Rubber (SBR) latex, and Waste Engine Oil (WEO). The incorporation of these materials aims to enhance the durability, flexibility, and sustainability of pavement structures.

To determine the most effective mix design, the test was conducted with varying proportions of RAP, SBR latex, and WEO, ranging from 3% to 7%. Each mixture was carefully analyzed for its stability, flow, and overall performance to identify the optimal combination. The best-performing proportion was then selected based on the test results to ensure improved pavement longevity and resistance to deformation.

The final results, detailing the effects of

different additive percentages on the mixed properties, are presented in Table 3.

TABLE III. MARSHALL TEST RESULTS

Sl.no	Parameters	VG 30	SBR modified Bitumen	SBR with WEO	Limits as per MoRTH
1	Marshall stability (kN)	10.57	15.13	17.54	Min 9
2	Flow value (mm)	2.80	3.67	3.72	2-4
3	Marshall quotient (1/2)	3.775	4.12	4.71	2-5

The Marshall Test results indicate that SBR-modified bitumen significantly enhances the performance of bituminous mixtures compared to conventional VG 30 bitumen. The stability values for SBR-modified mixes (15.13 kN and 17.54 kN) are notably higher than VG 30 (10.57 kN), demonstrating improved resistance to deformation under load. Flow values (3.67 mm and 3.72 mm) remain within the acceptable range of

2–4 mm, ensuring adequate flexibility to withstand traffic-induced stresses without cracking. Additionally, the Marshall Quotient, which reflects the balance between stability and flexibility, is higher for SBR-modified mixes (4.12 and 4.71) than VG 30 (3.775), indicating better resistance to rutting and fatigue. Overall, the results confirm that SBR modification enhances both the strength and durability of bituminous mixes, making it a superior choice for long-lasting pavement construction. The comparison between VG 30 and SBR-modified bitumen is illustrated in Fig. 1and 2.

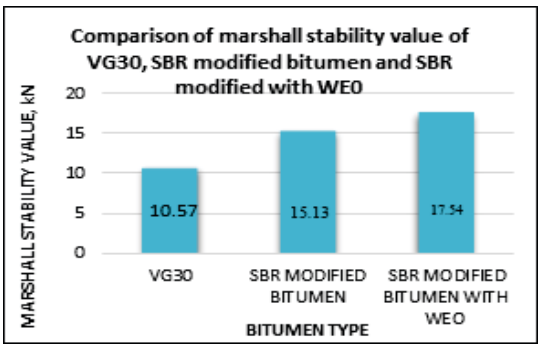

Fig 1: Comparison of Stability Value

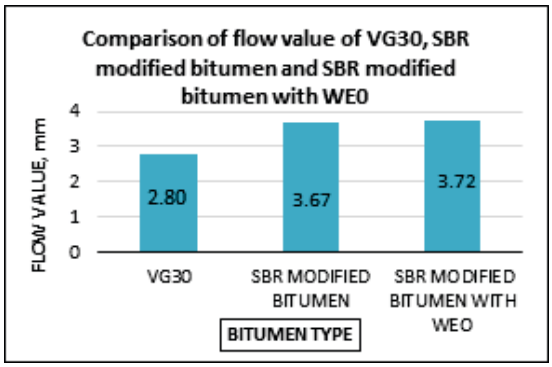

Fig 2: Comparison of Flow Value

The graph illustrates the Marshall Stability values for VG 30, SBR-modified bitumen, and SBR-modified bitumen with WEO, emphasizing the improvements achieved through modification. VG 30 bitumen exhibits the lowest stability value of 10.57 kN, indicating reduced resistance to deformation. However, when modified with SBR, the stability increases to 15.13 kN, signifying enhanced load-bearing capacity and durability. Further modification with WEO results in the highest stability value of 17.54 kN, indicating a more robust and resilient mix. Since higher stability values correspond to better resistance against traffic loads and rutting, the findings confirm that incorporating SBR and WEO into VG 30 significantly enhances its performance, making it more suitable for long-lasting pavement construction.

The optimal bitumen content has been determined as 4.5%, ensuring a well-balanced mix. The inclusion of optimized RAP content, natural aggregate, and additives contributes to improved durability, cost-effectiveness, and sustainability. The Marshall Stability value of 17.54 kN for the modified mix exceeds the minimum requirement of 9 kN as per MoRTH Clause 500.11. The flow value of 3.72 mm falls within the acceptable range of 2–4 mm, and the Marshall Quotient (stability/flow) of 4.71 also lies within the specified limit of 2–5, ensuring compliance with MoRTH standards and confirming the

mix's suitability for pavement applications.

VII. RESULTS AND DISCUSSIONS

The comparison between RAP (Reclaimed Asphalt Pavement) and natural aggregate demonstrates that both materials meet the required standards for pavement construction. The Impact Value remains within the permissible limit of 30% as per IRC guidelines, indicating sufficient toughness to withstand traffic loads. The Crushing Value, which determines resistance to compression, is within the 40% limit, ensuring the material's ability to resist fragmentation under stress. Likewise, the Los Angeles Abrasion Value is below 35%, confirming durability against wear and surface degradation due to vehicular movement. Additionally, the specific gravity of both RAP and natural aggregate falls within the acceptable range of 2.6 to 2.9, indicating consistency in material properties and ensuring compatibility in bituminous mix designs. Since both RAP and natural aggregate comply with IRC specifications for strength, durability, and resistance to deformation, they can be effectively utilized in pavement construction, contributing to cost efficiency and sustainability by incorporating recycled materials.

The viscosity of both normal and modified bitumen falls within the acceptable range of 60–140 seconds, ensuring proper workability, ease of mixing, and adequate coating of aggregates. The ductility of both bitumen types exceeds 75 cm, which is crucial for flexibility and resistance to cracking under varying traffic and temperature conditions. The Flash and Fire Point test results for normal and modified bitumen exceed 220°C and 260°C, respectively, ensuring sufficient resistance to fire hazards and high-temperature stability. Additionally, the softening point of normal bitumen is above 45°C, which helps maintain its stability under elevated temperatures, reducing the risk of rutting and deformation.

The Marshall Test results further confirm the suitability of the modified bitumen mix for pavement applications. The Marshall Stability value for the modified mix is 17.54 kN, which is significantly higher than the minimum requirement of 9 kN as per MoRTH Clause 500.11, ensuring improved structural integrity and load-bearing capacity. The flow value of 3.72 mm falls within the permissible range of 2–4 mm, indicating an optimal balance between stability and flexibility to withstand traffic-induced deformations. Additionally, the Marshall Quotient (stability/flow ratio) is 4.71, which is well within the standard limit of 2–5, signifying that the mix has an ideal combination of strength and workability.

Overall, the results demonstrate that the incorporation of RAP, SBR latex, and Waste Engine Oil (WEO) in bituminous mixes enhances the mechanical properties of the pavement while ensuring compliance with regulatory standards. The use of modified bitumen improves stability, durability, and flexibility, making it a superior alternative to conventional VG 30 bitumen. Moreover, the integration of reclaimed and modified materials promotes environmental sustainability by reducing waste, conserving natural resources, and lowering construction costs, ultimately contributing to the development of long-lasting, high-performance road infrastructure.

VIII. CONCLUSION

Reclaimed Asphalt Aggregate (RAA) plays a crucial role in sustainable road construction by reducing waste, conserving natural resources, and minimizing the demand for virgin aggregates and bitumen. The use of RAP enhances the mechanical properties of asphalt mixtures, improving stiffness, strength, and durability, which contributes to longer-lasting and more resilient pavements. Additionally, incorporating RAP lowers construction costs by reducing the need for new raw materials and cutting energy

consumption associated with asphalt production. Styrene Butadiene Rubber (SBR) is an effective asphalt binder modifier that enhances elasticity, durability, and resistance to common pavement distresses such as cracking, rutting, and fatigue failure. SBR-modified asphalt also improves adhesion between aggregates, making it highly suitable for roads exposed to heavy traffic loads and varying environmental conditions. This results in a pavement that maintains its structural integrity over time, reducing the frequency and cost of maintenance.

When combined with Waste Engine Oil (WEO), RAP and SBR create a high-performance asphalt mixture with enhanced functional properties. WEO improves adhesion, increases moisture resistance, and enhances workability, allowing for better compaction and uniform distribution of the mix. Additionally, the use of WEO provides an environmentally friendly solution for waste disposal by repurposing used engine oil that would otherwise pose ecological hazards. By integrating RAP, SBR, and WEO, the asphalt industry can promote sustainable construction practices that reduce reliance on virgin materials, minimize environmental waste, and enhance the overall performance and longevity of road infrastructure. These modifications not only improve pavement quality but also contribute to more cost-effective and eco-friendly road networks, making them a viable solution for modern transportation infrastructure.

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DESIGN AND FABRICATION OF REMOTE-CONTROLLED TILLING, WEEDING AND SEEDING MACHINE

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ABSTRACT

There has been a transformation in agriculture during the recent years from conventional to modern. Researchers and innovators are searching for ways to overcome the inefficiencies in conventional techniques. Agriculture went through a transformative phase when automation and electric components were used to enhance and speed up farming processes. These technological advancements aim to lower the labour intensity of the process while significantly raising productivity and efficiency in agricultural production. Automating agricultural machine will add to the ease and cost reduction in farming. This project aims to manufacture a machine which can be controlled remotely and is capable of performing major operations like tilling, weeding and seeding.

Keywords: Automate, agriculture, remote, farming

I. INTRODUCTION

Throughout the 20th century, conventional agricultural techniques were mostly used to produce crops. However, when the need for food production increased, these traditional methods proved to be very ineffective. One of the primary drawbacks was the substantial amount of human work required, which resulted in a labour intensive process, that regularly failed to meet the rising global food demands. Automating agricultural machine will add to the ease and cost reduction in farming. This project aims to manufacture a machine which can be controlled remotely and is capable of performing major operations like tilling, weeding and seeding operation.

The existing machine is a tiller machine which operates with the help of gasoline or electric motor to drive the blades into the soil. The main application of tiller machines is in the agricultural field. It is mainly used to facilitate soil preparation for planting or for the preparation of the bed. Here the blades are forced towards the ground; the machine digs up the soil, breaks it down, and turns it over. The blades are arranged in a revolving drum. In addition to aerating the soil, the blades' revolving movement aids in the assimilation of nutrients and organic materials, creating a healthier growth environment for crops.

[1] contributes to the need of suitable mechanization for small farmers and the demand for effective, reasonably priced, and regionally relevant solutions. The influence of these technologies on increasing production, decreasing manual labor, and promoting sustainable agricultural methods has been highlighted by earlier research. Difficulties include accessibility to technology, local terrain variation, and economic issues. The study offers some guidance on how to get beyond these obstacles and go forward with the creation of power tillers that are specifically designed to meet the requirements of farmers in underdeveloped countries.

The authors in [2] have focused on the problems that exist today with conventional soil preparation and seed distribution techniques and emphasize the importance of creative solutions for maximizing seed

spacing and placement. Pneumatic seeding system developments are covered in earlier research, with an emphasis on how they may improve agricultural cultivation's precision and efficiency. The study offers insightful information on how to develop and test a new seed delivery system that addresses important facets of sustainable crop production and precision agriculture.

The review in [3] highlights how automation is becoming more important in tackling issues such improving precision farming and labor shortages. Studies that have already been done cover autonomous robot applications in enclosed spaces, in sensing technologies, navigation, and crop monitoring. This study highlights how these robots might maximize resource use, reduce environmental effect, and raise agricultural productivity all around.

[4] mainly focuses on current traction control systems, highlighting how important throttle actuation is to car dynamics. It explains the difficulties in sustaining ideal traction in earlier research, particularly in a variety of driving scenarios. The evaluation explores developments in actuators, sensors, and electronic control systems to enhance the effectiveness of traction control. Gaining an understanding of and improving these systems is essential to raising overall car performance and safety.

Importance of weeding in paddy agriculture in order to maximize crop output is discussed in [5]. The journal paper explores the literature on inter-row weeding devices, highlighting the critical impact that blade design plays in weeding. Efficient elimination of weeds, soil effect, and adaptation to paddy field conditions are important factors to be taken into account. It is expected that the study would advance sustainable methods in rice agriculture, improve the effectiveness of inter-row weeding wheels, and provide insights into optimizing blade characteristics.

An extensive literature survey has been carried out on different aspects of the operation of the machine and the following conclusions are made about the machines that currently exists:

1) Requires a highly skilled operator for ensuring the proper functioning of the machine.

2) Specialized training of operators is key factor in maintaining machine efficiency.

3) The reliance of human operators introduces to many limitations such as human fatigue, potential error and require the need of break.

II. COMPONENTS

This is an agricultural machine that utilizes the engine's output. The engine used is a 150cc GY6 with a continuously variable transmission. The engine's power is transmitted directly to the tilling blades via a chain and sprocket system. The speed of the tilling blades can be changed by adjusting the throttle. The tilling blades mechanically overturns the soil, preparing it for crop planting. The ridger is used to form ridges or raised beds in the soil. This aids in weed management and soil aeration, allowing for healthy root development. The seeding unit distributes the required number of seeds into the soil. The bed maker covers the seeded portion with soil. The entire process is remotely controlled, allowing for precise management of motors that adjust the height and depth of the tilling blades as well as control the rotation of the seeding unit. Accordingly, a rough conceptual design was sketched out and Fig. 1 show the entire assembly.

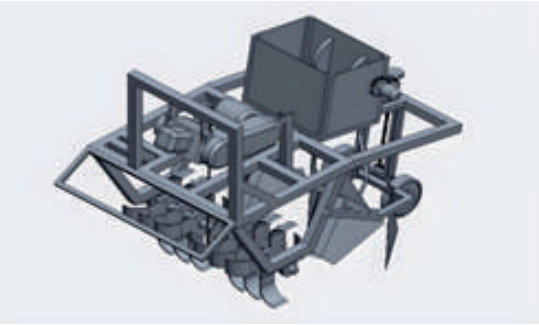

Fig.1: 3D model of the tilling, weeding and seeding machine

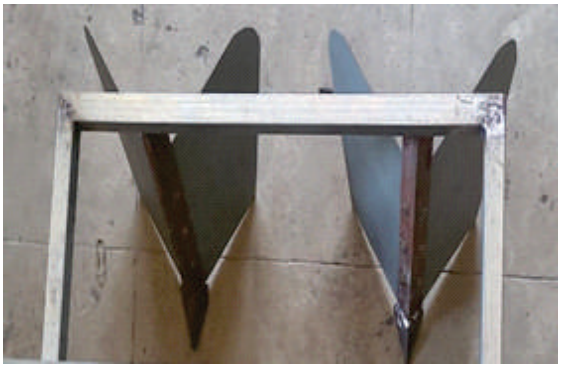

Fig. 2: Tilling Blades

The components of the tilling- weeding-seeding machine are

- Tilling Blade
- Ridger Blade
- Bed Maker
- Seeder Unit

A. Tilling Blade

In agricultural machinery, a crucial part of the cultivation process is soil preparation, and tilling blades are essential to this process. These blades are meant to break up and turn over soil, making seedbed preparation and weed management easier. Tilling blades are made to fit a variety of soil types, agricultural techniques, and environmental circum stances. They are available in a range of sizes, shapes, and combinations. Based on the tillage required tilling blades of 10 HP capacity was opted as in Fig. 2. The agricultural machine for tilling, weeding, and seeding was effective due to the improved performance of the resulting tilling blade configuration in terms of soil turnover, weed suppression, and overall efficiency.

B. Ridger Blades

Ridger blades are core part of agricultural machinery. Agricultural machinery that is used to make ridges or furrows in the soil must have ridger blades. The most common planting crops are potatoes, vegetables, and sugarcane. These blades play a critical role in shaping the soil to create raised planting beds, facilitating proper drainage, soil aeration, and preservation of moisture. The best planting conditions and soil preparation were achieved through careful planning and application of ridger blades. The fabricated ridger blades as in Fig. 3 were designed to minimize surface disturbance and soil compaction while producing uniform ridges effectively. The agricultural machine's effective incorporation of ridger blades enhanced crop productivity, soil management, and overall farming efficiency. The ridger blades' reliability and performance highlight their significance as essential parts of modern agricultural equipment, encouraging effective and sustainable crop production methods.

C. Bedmaker

A bed maker is an essential piece of tool in agricultural practices that is used to make raised planting beds or seedbeds, especially in row crop cultivation. This machinery is essential in forming the soil into even beds with exact sizes and separations, which promotes healthy plant development,

irrigation, and weed control. In order to prepare the soil for planting in an efficient and effective manner, the bed maker's design and implementation were essential. The selected bed maker was designed to efficiently generate raised beds with uniform height, width, and spacing, appropriate to our target crops' particular needs and agricultural methods. The quality of the bed formation, the quantity of soil disturbance, and the overall operational efficiency was ensured through field trials, which confirmed the bed maker's efficiency in producing ideal planting conditions. The successful incorporation of the bed maker as in Fig. 4 into the farming apparatus signifies an important progression in soil preparation technology, providing farmers with a flexible and dependable instrument that can increase crop yield, optimize resource utilization, and augment farming sustainability overall.

Fig. 3: Ridger Blades

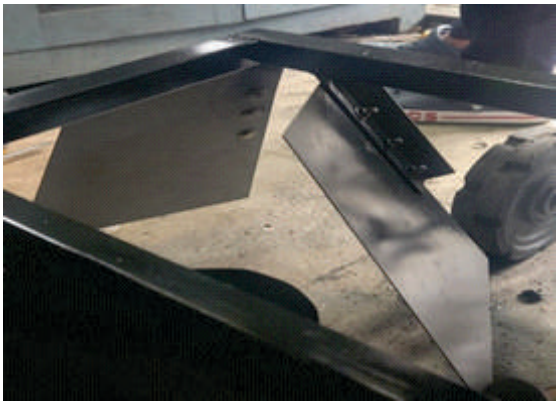

Fig. 4: Bedmaker

D. Seeder Unit

An essential component of agricultural equipment for precisely and effectively planting seeds in prepared soil beds is the seeder unit. This component is essential to automating the seeding process because it ensures consistent seed depth, spacing, and placement, which maximizes sprouting and growth of the crop. The selected seeder unit was designed to accept different kinds and sizes of seeds. Here with the help of wiper motor as shown in Fig. 5, required operation was achieved so as to carry on with the planting operation. The performance, accuracy of seed placement, and overall operational efficiency of the seeder unit had been evaluated through a rigorous testing and validation process.

Fig. 5: Seeder Unit

III. FABRICATION

The steps in creation of a semi-automatic tilling, weeding, and seeding machine is

explained below. Throughout the fabrication process, various components are meticulously crafted, assembled, and tested to ensure peak performance and durability. Every step of the fabrication process, from selecting high-quality materials to precision machining and assembly techniques, contributes to the creation of a strong and functional agricultural machine. This section of the report delves into the difficulties of fabrication, providing insights into the methods, techniques, and considerations required to bring a semi-automatic tilling, weeding, and seeding machine from concept to reality. The whole fabrication process was divided into various sections:

A. Procurement of suitable materials

According to the design and specifications of the tilling, weeding, and seeding machine, appropriate materials were procured to fabricate the agricultural machine.

B. Fabrication of the rotor

Based on the required specifications, a shaft with a diameter of 30mm and a length of 750 mm was selected. The shaft was divided into 7 sections. The middle section serves as a chain sprocket, while the remaining sections are affixed with square plates. These square plates feature holes at the center and corners. Subsequently, the square plates are welded onto the main shaft. The welded plates on the main shaft are depicted in Fig. 6.

Fig. 6: Main Shaft

C. Fabrication of the main frame

The construction of main frame, commenced by meticulously selecting robust materials renowned for their durability. In line with this objective, a GI pipe measuring 1.5 inches was selected. Subsequently, it was proceeded to cut and shape metal components with precision, adhering closely to the detailed design specifications. Throughout the fabrication process, stringent attention was paid to ensuring the quality and finish of each component. This meticulous approach ensured that the final main frame attained the desired structural integrity and aesthetic appeal. The completed main frame is shown in Fig. 7.

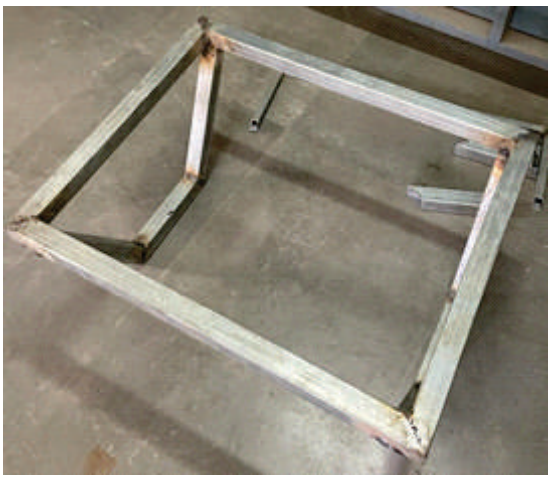

Fig. 7: Main Frame

D. Fitting of main shaft

Tilling blades with a suitable load capacity were meticulously chosen for the agricultural machine, as depicted in Fig 8. These blades are affixed to the main shaft, which has a load capacity of 10 HP. Here, the tilling blades are securely attached to the main shaft using nut and bolt fixtures, as illustrated in Fig. 8. The selection of these blades is based on their effectiveness in overturning the soil, ensuring optimal tilling results.

Fig. 8: Tilling Blades attachment

After attaching the tilling blades to the square plates, the main shaft is secured to the main frame using a pillow block (P206). Positioned on the sides of the main frame, the pillow block facilitates the rotation of the main shaft, as depicted in Fig. 9.

E. Fabrication of ridger attachment

For the fabrication of the ridger attachment, a Japan sheet was opted due to its high strength and superior durability characteristics. These sheets were cut into a specific shape, forming a triangle with two sides when two sheets are combined. To securely fix these sheets together, suitable L clamps were utilized, and the metal sheets were bolted using nut and bolt fixtures.

Fig. 9: Main shaft attachment to the main frame

F. Fabrication of Seed storage unit

The fabrication of the seed storage unit entails the use of a 0.5-inch GI pipe as the supporting frame, with Japan sheet serving as the covering for the box. To facilitate the supply of seeds to the soil, rollers are employed. A portion of the Japan sheet is cut into a rectangular shape to ensure unrestricted rotation of the rollers. The rollers themselves are crafted from plywood material, consisting of three plywood sheets, each 10mm in thickness, layered together to form a roller. This process is repeated to create a second roller. A shaft is then passed through the center of each roller, as depicted in Fig. 10, to facilitate the seed supply process. The rotation of the rollers is accomplished using a wiper motor, ensuring a smooth and efficient distribution of seeds onto the soil.

Fig. 10: Seeder Unit

G. Fabrication of Engine Mount

In the fabrication of the engine mount, meticulous attention was paid to ensure proper fitting and attachment of the engine. This involved utilizing 1.5-inch GI pipe and flat plates for securing the engine. The flat plates were welded onto the GI pipe, providing a sturdy base for the engine. The engine was then securely fastened to the main frame using nut and bolt fixtures, as depicted in Fig 11. This fixture ensures a reliable and stable attachment of the engine to the agricultural machine's main frame, thereby facilitating smooth and efficient operation.

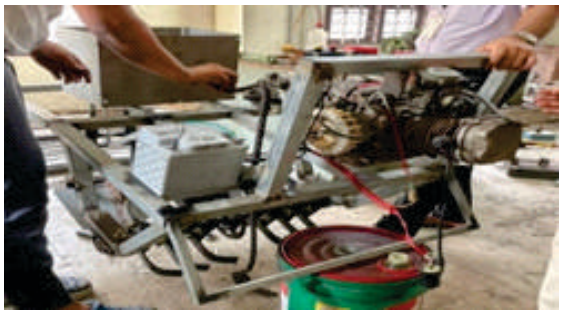

Fig. 11: Engine Mount

H. Fabrication of bedmaker

The primary function of the bedmaker is to gather soil to cover the developed ridges. For this purpose, the bedmaker is constructed using 1-inch square GI pipe and 1mm thick Japan sheet. The GI pipe is cut and welded according to specified dimensions, ensuring structural integrity and durability. These components are then fused together and welded onto the main frame to enhance strength and stability. Additionally, Japan sheets are cut into parallelogram shapes as per the specified design requirements. These sheets are then bolted together to form the desired configuration. L clamps are welded to the frame and attached to the main frame, providing secure fixation. This meticulous fabrication process ensures that the bedmaker is robust, reliable, and capable of effectively performing its intended function in agricultural operations.

I. Fabrication of Control Unit

Control unit is made of Arduino UNO, 2-channel relay, joystick. Here the function of the machine is carried out by using 2 UNO boards, 2-channel relay (2PCS). Arduino Uno R3 is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller as shown in Fig 12. It can be connected to a computer with a USB cable or can be powered with a DC adapter or battery to get started.

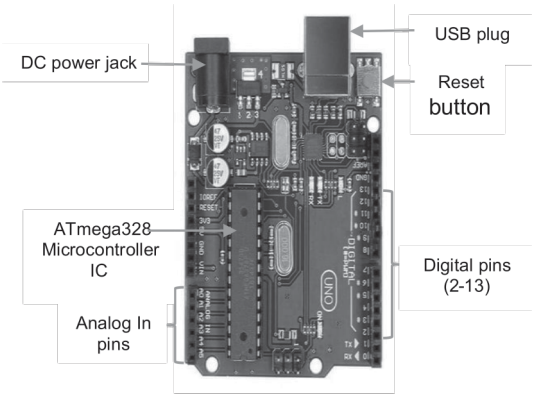

Fig. 12: Control Unit

IV. CONCLUSION

In conclusion, the design and building of a multipurpose tilling, weeding, and planting machine represents a significant step forward in agricultural innovation. Advanced technologies were implemented to manage manpower shortages, optimize resource utilization, and boost agricultural productivity. The use of this technology streamlines agricultural activities, increasing production while avoiding negative environmental implications.

The successful completion of this project demonstrates the possibility of revolutionary changes in modern agriculture to satisfy the sector's changing demands. Ongoing research and development in this subject may result in

continual improvements to agricultural gadgets, making future farming processes more sustainable and technologically advanced around the world.

The machine helps farmers by reducing manual labor and increasing productivity. This leads to better crop yields and more sustainable farming practices. It also

improves farmers' livelihoods by making their work easier and more efficient.

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WEIGHT GOVERNOR

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ABSTRACT

In modern transportation systems, maintaining optimal vehicle performance while ensuring safety is crucial. One of the key factors in achieving this balance is the ability to monitor and control a vehicle's weight, which directly affects its stability, efficiency and wear on critical components. Overloading a vehicle can lead to numerous issues such as loss of control. This paper presents the design and implementation of an IoT-based prototype vehicle, controlled by the L298N motor driver, which adjusts its speed in response to varying weight conditions. The vehicle utilizes a load sensor to detect the weight placed on it and based on this input, the speed of the DC motors is automatically regulated. When the load exceeds a predetermined threshold, the vehicle's speed is reduced to make sure that vehicle operate efficiently and safely. Furthermore, the system integrates an IoT-based notification mechanism via the internet to send real-time notifications to authorities. The microcontroller processes the data from the load sensor and manages both the motor control and the notification system. This approach enhances the vehicle's operational safety and efficiency by providing immediate alerts when excessive weight is detected. The paper discusses the hardware setup and integration of IoT to the system to alert the authorities to ensure safety and enforce regulations.

Keywords: Weight governor, Load cell, PWM control, Threshold detection, Iot based notification, Remote monitoring

I. INTRODUCTION

The Weight Governor is an innovative system designed to address the challenges of overloaded vehicles by providing real-time monitoring and automatic speed adjustment based on the vehicle's weight. Using a combination of load cells, motor control systems and real-time data processing, the Weight Governor ensures that the vehicle remains within safe operational limits while preventing overloading.

The Weight Governor is an advanced system that enhances vehicle safety and efficiency by monitoring and controlling the vehicle's weight in real-time using load cells. It ensures that the vehicle does not exceed a predefined weight threshold preventing hazards like loss of control, tire damage and suspension strain. When weight on the vehicle exceeds the limit speed of the vehicle is decreased. This helps to the improve control and stability particularly when carrying heavy or unbalanced loads and ensures compliance with weight regulations. The mechanism can be demonstrated using a prototype vehicle that works using a microcontroller and motor driver, when the weight exceeds the limit, the system automatically reduces the speed through Pulse Width Modulation (PWM) on L298N motor driver.

In addition to safety, the Weight Governor offers cost-saving benefits by reducing wear on critical components like tyres, suspension and the motor which extends the vehicle's lifespan and lowers maintenance costs. Notifications are sent to authorities when the

weight limit is surpassed, enabling quick action to prevent legal violations. Overall, the system provides a scalable, reliable solution for various vehicles, including heavy-duty trucks, delivery vans and passenger cars, ensuring optimal performance and compliance. The integration of this system not only enhances safety but also contributes to more efficient vehicle operation and better resource management in the long term.

II. LITERATURE SURVEY

Various papers that have been reviewed for the implementation of the proposed system. [1] provides an in-depth examination of Weigh-In-Motion (WIM) systems, which are essential for measuring vehicle weights as they move across roads. These systems help identify overweight vehicles which can cause significant damage to road infrastructure. WIM systems come in two main types: low-speed (LS-WIM) and high-speed (HS-WIM). LS-WIM systems typically require vehicles to travel at speeds of 10 to 20 km/h and are commonly located near toll booths while HS-WIM systems can measure the weight of vehicles traveling at speeds up to 90 km/h. Accurate weight measurement is challenging due to dynamic loads that vary with factors such as vehicle type, road conditions and environmental factors. The paper also highlights various sensor technologies used in WIM systems, including load cells, bending plates, piezoelectric sensors and fibre optic sensors. Each sensor type has its own strengths and weaknesses in terms of accuracy, cost and durability. Calibration is crucial for maintaining accuracy, with methods including static calibration, dynamic calibration and continuous auto-calibration. Additionally, the paper discusses different algorithms for weight estimation, such as the Mean Value Estimator and the Maximum Likelihood Estimator (MLE), which improve precision by factoring in sensor uncertainties. The paper concludes by emphasizing the need for further research to address existing gaps and improve the practical effectiveness of WIM systems [1].

An IoT-based vehicular overload detection system designed to protect flyovers in India where overloaded trucks are a major cause of structural failures is presented in [2. These overloads often lead to flyover collapses resulting in significant economic losses and safety risks. To address this, the system uses load cells placed at checkpoints before flyover entrances to measure the weight of vehicles in real time. If a vehicle exceeds the allowed weight limit, the system keeps the exit gate closed, preventing access to the flyover and redirects the vehicle to an alternative route using its navigation system. This proactive solution aims to reduce the risk of flyover damage and improve road safety. The paper emphasizes the urgent need for a reliable solution to monitor and control vehicle weight on flyovers. The proposed system uses load cells at a weighing station to accurately measure vehicle weight with a microcontroller processing this data and comparing it to a predefined threshold. If the vehicle's weight is within the limit, the gate opens allowing passage. If not, the gate remains closed and the vehicle is rerouted. The authors advocate for the implementation of this system, suggesting that with government support it can be integrated into existing infrastructure helping to prevent flyover collapses for ensuring the safety and longevity of critical transportation structures across India [2].

A smart vehicle management system designed to enhance road safety by preventing accidents caused by driver drowsiness, alcohol consumption and vehicle overload is presented in [3]. The system integrates three primary detection mechanisms: a drowsiness detector that utilizes facial recognition and eye-blinking analysis, an alcohol detector that employs a gas sensor to assess the driver's breath for alcohol presence and an overload detector that measures the weight of passengers in the

vehicle. By employing Raspberry Pi and Arduino Uno microcontrollers, the system processes data from these sensors and provides real-time alerts through a buzzer and GSM module to ensure immediate communication with a control room. The load detection component of the system relies on a load cell, which is strategically placed beneath the vehicle's floor to accurately measure the total weight exerted by passengers. This load cell continuously monitors the weight and compares it against a predefined threshold. If the load exceeds this limit, the system activates an alarm, displays the overload status on an LCD and initiates a slowdown of the vehicle's engine to mitigate the risk of accidents associated with overloading. Overall, the paper aims to significantly reduce traffic accidents by leveraging modern technology to monitor and enhance driver and passenger safety [3].

III. SYSTEM ARCHITECTURE

The system architecture involves several key components that work together to control the vehicle's speed and send overload notifications when the weight exceeds a threshold.

1) Weight Measurement and Monitoring

The system begins with capturing and processing the weight applied to the vehicle. The load cell measures the weight and sends an analog signal to the HX711 amplifier which amplifies the signal and converts it to a digital format since HX711 is an amplifier as and an ADC. The HX711 is connected to the ESP32 microcontroller via two pins (Data and Clock).

The ESP32 reads this digital signal in real-time and processes it to monitor the current weight of the vehicle. Using this information the speed of the vehicle is controlled. As the weight increases, the ESP32 continuously checks and updates the weight reading, allowing the system to take further action based on this data [[4],[5],[6],[7],[8].

2) Vehicle Speed Control

Once the ESP32 processes the weight data from the load cell, it uses this information to control the speed of the vehicle. The ESP32 generates PWM signals which are sent to the L298N motor driver. The motor driver then adjusts the speed of the DC motors accordingly. As the weight on the vehicle increases, the PWM signal is adjusted thus effectively reducing the motor speed to ensure that the vehicle doesn't exceed safe operational limits.

The L298N motor driver is connected to the ESP32 via its PWM pins, which control the motors speed based on the processed weight data. This dynamic control of motor speed ensures that the vehicle operates safely under varying load conditions. The weight is classified into three ranges and the speed is controlled according to the weight [3] .

3) Threshold Detection and Alerts

To ensure that the vehicle operates within safe weight limits, the ESP32 continuously compares the real-time weight data with a predefined threshold. If the weight exceeds this limit, the system triggers an alert. The ESP32 sends this alert via Wi-Fi to a connected IoT platform such as Blynk, which allows remote monitoring.

When the weight exceeds the threshold, the ESP32 transmits this data to the IoT platform, which processes it and sends an immediate notification to the user or relevant authorities. This alert can include the current weight and operational status of the vehicle. The LED's connected to the ESP 32 can alert the driver whether the vehicle is overloaded as three LEDs can represent three ranges of weight[3],[6].

4) IoT Communication and Remote Monitoring

The ESP32 is connected to the internet via Wi-Fi allowing it to send real-time data to an IoT platform like Blynk. This platform provides

remote monitoring of the vehicle, displaying data such as weight and overall vehicle status. If the weight exceeds the predefined threshold, the ESP32 sends an alert to the IoT platform which then notifies the authorities. This IoT communication not only allows for real-time monitoring of the vehicle's status but also ensures that authorities are immediately informed if the vehicle is overloaded, even from a distance[5],[6].

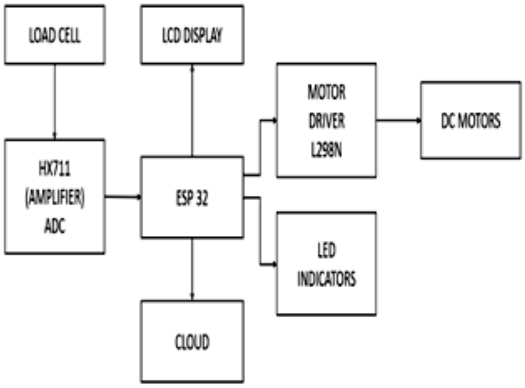

Fig. 1: Block Diagram of Proposed System

TABLE 1. TABULAR REPRESENTATION OF RELATION BETWEEN WEIGHT AND SPEED

Weight on vehicle(grams)	PWM Values
0-20 g	255
20-50g	150
50-80g	100
Above 80g	0

Experimental results as documented in Table 1 demonstrate the inverse correlation between vehicle weight and motor speed. Specifically, Table 1 presents discrete measurements of motor speed, quantified in Pulse Width Modulation (PWM) values as a function of incremental weight loads in grams. Observed data indicate a consistent decrease in motor speed with increasing weight, validating the system's dynamic speed adjustment mechanism.

Fig. 2 provides a graphical representation of this relationship, depicting motor speed as a function of weight. The resulting graph exhibits a negative slope that visually represents the inverse relationship between weight on vehicle to speed of vehicle . This visual and tabular data collectively highlights how the mechanism can control the speed of the vehicle depending upon the weight on it.

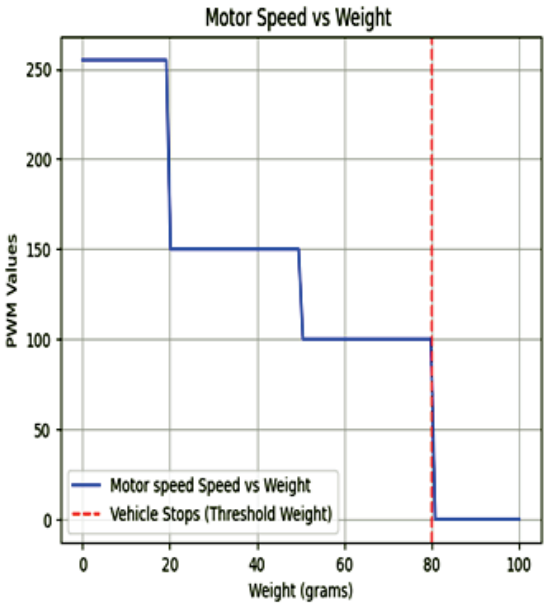

Fig. 2: Graphical Representation of Relation Between Weight and Speed

IV. RESULTS AND DISCUSSIONS

The paper successfully demonstrates the integration of weight-based speed control in a prototype vehicle that uses the L298N motor driver, load cell and ESP32 microcontroller. The system not only adjusts the speed of the vehicle based on its weight but also incorporates an IoT-based notification system to alert authorities when the weight limit is exceeded. The system has successfully achieved the objective.

1) Speed control mechanism

The L298N motor driver controlled via Pulse Width Modulation (PWM) signals effectively adjusts the vehicle's speed based on the weight input. As the weight increases, the system proportionally reduces the motor speed. This adjustment is made in real-time to prevent excessive load from compromising the vehicle's functionality.

2) Reliability in weight measurements

The load cell provides accurate and reliable measurements of weight, allowing the system to make precise decisions. The real-time processing by the ESP32 microcontroller ensures that the system operates without delay.

3) IoT integration for notification

IoT functionality adds a significant layer of safety and monitoring by sending immediate notifications to the authorities. This improves the management of weight compliance in real-time.

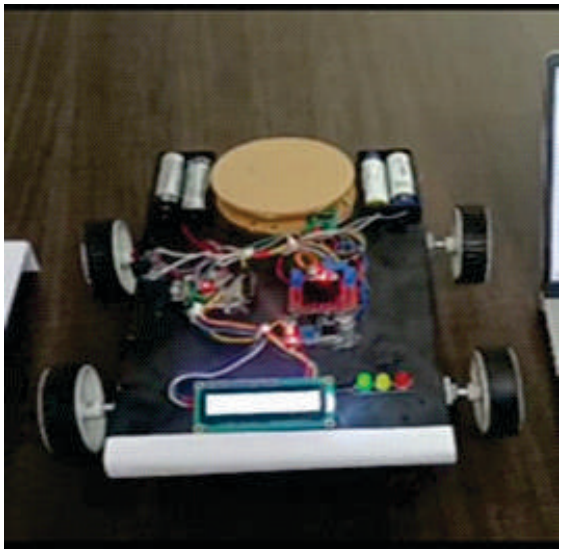

Fig. 3: Final Product

V. CONCLUSION AND FUTURE ENHANCEMENTS

Weight Governor system offers an effective approach in regulating vehicle speed based on weight. By incorporating an ESP32 microcontroller, L298N motor driver and load cell, the system successfully reduces speed as the weight increases, ensuring safer operation. Additionally, the IoT-enabled notification system provides real-time alerts to authorities when the weight surpasses a predefined threshold for enhancing safety and compliance. The integration of these technologies results in a scalable and efficient solution that can be applied to various domains including transportation, logistics and regulatory monitoring.

This paper demonstrates the potential of combining IoT and embedded systems to improve vehicle control and safety, paving the way for future innovations in weight-based automated systems. Some of the possible enhancements are:

- Enhanced Load Detection and Accuracy: Upgrading to more precise sensors or refining load cell calibration could improve the accuracy of weight measurements, leading to more reliable speed control.
- Integration of GPS for Location-Based Alerts: Adding GPS capabilities would allow for location-specific alerts to be sent to authorities improving monitoring in restricted or regulated areas.
- AI-Based Predictive Maintenance: By using artificial intelligence to analyze system data, the vehicle could predict maintenance needs (e.g., motor wear or load cell degradation) and notify the operator for enhancing the system's longevity.
- Predictive Maintenance: Analyze weight and speed data over time to predict potential maintenance needs, such as tyre wear or suspension issues. This would enable proactive maintenance scheduling and reduce downtime.

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IMPLEMENTATION OF AN E – KICK SCOOTER

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ABSTRACT

The project is an ambitious venture in designing and implementing an advanced e-kick scooter with a robust anti-collision warning system. The overall objective is to improve safety and provide an efficient, ecofriendly means of transportation. The proposed product is specifically designed to be operated in areas like IT parks, college campuses, airports and large infrastructure facilities, where mobility solutions can be illustrated properly for enhancing productivity and convenience. Ergonomic principles are followed at the design stage and ensured that the scooter is functional and cozy too. The construction of the main body of the scooter uses a material that is both lightweight and durable. The anti-collision warning system is an essential component of this scooter. By using ultrasonic sensors placed in the scooter, possible colliding objects at a maximum distance of 250 cm can be detected. Once it detects the object, it applies the brakes automatically, which allows the rider to stay more alert and helps reduce the risk of crashing the bike. The scooter is powered by high-capacity lithium-ion batteries, offering a range of approximately 25 kilometers on a single charging. The goal of this cutting-edge electric kick scooter is to offer useful solutions for a range of expansive facilities. The scooter makes it simple to move around large spaces like corporate campuses and IT parks, increasing worker mobility and productivity.

Keywords: Carbon footprint, mobility, Ergonomic design, Urban transportation

I. INTRODUCTION

Growing awareness of environmental sustainability and fast-paced technological developments have caused a major change toward electric mobility. Among these, electric kick scooters (e-kick scooters) have become rather common and useful for municipal mobility. Particularly suited for short- distance trips inside metropolitan areas, they provide an easily available, environmentally friendly, and reasonably priced means of transportation. For commuters wishing to avoid business traffic and lower their carbon footprint, e-kick scooters are light and simple to operate. Including electric propulsion in e-kick scooters not only improves their performance but also helps to lower noise levels and air pollution in local communities.

The proposed study includes design, development, testing and examines the entire process of developing an

e-kick scooter. Designing a dependable and efficient kick scooter that satisfies ultramodern civic commuters' needs is the goal of this project.

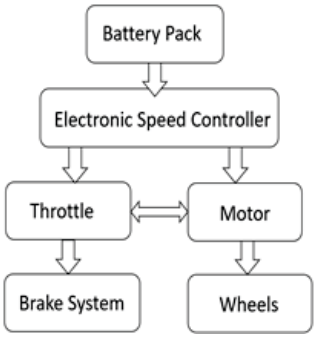

Fig.1: Block Diagram of the Proposed E-Kick Scooter.

This paper attempts to provide a comprehensive awareness of the engineering and technological issues involved in designing a functional e-kick scooter by investigating the selection and integration of critical factors like the brushless DC motor, battery, throttle and controller.

This design is significant since it support sustainable transportation. Using the features of ultramodern technology, the deployment of e-kick scooters can significantly influence civic transportation, encourage environmental responsibility, and improve the quality of living of urban residents.

II. LITERATURE STUDY

With the increasing need of sustainable and efficient transportation solutions, there has been substantial research and development on electric micro-mobility products, in particular e-kick scooters. Efficient, compact and quick vehicles are ideal for short-distance commuting that could get rid of traffic congestion and carbon footprints.

A. Design and Manufacturing Considerations

[1] has brought out the complete process of e-kick scooters design and manufacture. Their research highlights the relationship between visual design and structural soundness, as well as manufacturability. This study emphasizes the need for standard design principles combined with appropriate manufacturing techniques to develop durable and efficient e-kick scooters. The paper provides a fundamental design for the manufacturing process of e-kick scooter.

Challenges associated with e-kick scooting in Indian road conditions is discussed in [2]. This study deals with designing and simulation studies of e-kick scooters that are able to resist the Indian road infrastructure, one of the toughest and diverse in the world. It confirms the need to take environmental variables into account and addresses durability concerns for a vehicle during design. This is an important study for designing e-kick scooter on bad road conditions.

In a more comprehensive manner, on design and production of electric scooters [3] includes many aspects of functions and performances. Not only about

e-kick scooters, this work provides useful information on the fundamentals of electric scooter, such as power systems, control activities and ergonomic aspects.

B.Implementation and Environmental Factors:

E-kick scooters require careful integration of environmental factors with user needs. It is essential to adapt designs to local road conditions to ensure safety and reliability. The study highlights the requirement of robust validation and testing to prove performance of e-kick scooters in real environment conditions.

III. PROPOSED SYSTEM

The system is designed to develop an e-kick scooter that is viable, durable and adaptable to various environmental conditions particularly in diverse road conditions.

A. Design and Manufacturing

- Modular Design: System is designed as modular, which means that it will be able to make changes and adapt with respect to different user needs as well environmental settings. This involves replaceable parts such as wheels, suspension and battery packs.
- Rigorous frame and body design: Taking into account the research in [1], the scooter is designed to provide a robust frame that can cope with the wear and tear of daily use.
- Manufacturability: Manufacturing processes can be improved in terms of cost and scalability to derive more value for the customer.
- Ergonomics: The design is ergonomical for user comfort and security, including adjustable handlebars, footrests that provides driver with some cushion and

intuitive controls.

B. Road Type Adaptation

• Weatherproof tyres: The system is fitted with tractor and motorcycle style tyres offering robustness against punctures so that there is optimal grip plus stability on a range of surfaces. The e-kick scooter is designed to maintain performance and reliability under wet, dusty, and hot conditions.

C. Electric Power and Control

• Efficient Electric Motor: The system incorporates an efficient electric motor that provides adequate power and acceleration for urban commutes.

• Long-Range Battery: The range of e-kick scooters has been increased with high capacity long life batteries, for normal everyday urban riding.

• Intelligent Control System: It provides motor control system, battery control and safety features at the same time providing the rider a smooth and safe riding experience.

D. Safety Features

• Reliable Braking System: The e-kick scooters has a reliable braking system, including both electronic and mechanical brakes, for safe and effective stopping.

• Integrated Lighting: The system incorporates an integrated front and rear lights, as well as turn signals, for enhanced visibility and safety.

IV. HARDWARE

A. Brushless DC Motor

In the e-kick scooter, hub motor is a key component which connect directly to Brushless DC motor (BLDC), and plays a major role in determining how efficient, high-performing, and sustainable the scooter can be. Together with the motor placed in the wheel hub, there is no need to use expensive chains or complex and high-maintenance mechanical transmission systems like belts. It offers high energy efficiency, hence extends battery life so that the scooter can go long distance in a single charging. Advanced electronic controllers in the BLDC hub motor delivers the ideal torque, and speed for a smooth and responsive ride on all terrains from flat to hilly place. It is well-suited for places like colleges and airports (where noise matters) due to the fact that it runs pretty quietly. The motor can also supply regenerative braking in some configurations to convert kinetic energy back to power, optimizing the energy usage. Utilizing these advanced features, the BLDC hub motor is a key component to fulfil the goals of safety, sustainability, and improved user experience.

B. Electronic Controller

Motor controller powering the e-kick scooter is the link between battery and BLDC hub motor. It controls electrical power delivered to the motor, in order to make it work safely and efficiently. Utilizing sophisticated control algorithms, the motor controller changes the voltage and current of that motor to control the speed, torque, and direction. This part accurately reads user inputs such as throttle control and converts them to corresponding motor actions for a smooth acceleration or deceleration. The primary function of the motor controller is to operate the scooter safely, integrating built-in protective features to prevent damage and ensure reliable performance. The technology includes overcurrent protection to ensure the safety of the motor during peak loads, thermal protection to prevent over- temperature, and low-voltage disconnect to protect the battery from deep discharging that increases the reliability, and longevity of scooter.

Another important component jointly powered by both the electric drive system and regenerative braking was the electric motor controller, which enables conversion of deceleration to electric energy for storage in the battery. This not only improves energy efficiency but also increases the range of the scooter. Moreover, the motor controller is integrated to facilitate the data between

battery, motor as well with the rest of the sub-systems in a seamless way, hence allowing reliable behaviour. In addition to these functions, the motor controller supports the overall safety, sustainability and user friendly operation of the e-kick scooter .

C. Battery

Battery is an essential part of designing and the e-kick scooter technology because it carries the only power that runs the whole system. The scooter battery is a 24V, 12Ah high capacity lithium-ion battery that has superior energy density, lightweight and long life. Configured in this way, the battery extends the scooter to a decent range of around 25 kilometres in single charging. The scooter works satisfactorily for different applications (IT parks, campuses and airports etc.).

The battery comes with the smart Battery Management System (BMS) and monitors voltage, current and temperature. This allows the battery to be operated continuously preventing problems of overcharging, deep discharging and overheating. These extra safeties have been implemented to improve the battery performance, reliability and operational life. The system also integrates regenerative braking which converts the kinetic energy during braking back to electrical energy and stores it in the battery, thereby improving energy efficiency.

Above all, the battery is built to be charged quickly, which minimizes downtime and makes it more practical. Its reliable performance is guaranteed under different environmental conditions, as the battery case is water and dustproof. The battery is also made out of recyclable and sustainable materials so that it is in accordance with project focus on sustainability. The 24-volt, 12 Ah battery is an important ccomponent of electric kick scooter and without it, we will not achieve the target of the project which is for safety, efficiency and to be Green.

D.Throttle

Throttle is one of most important hardware for an e-kick scooter implementation as it gives the rider good speed control of the vehicle. The throttle is usually an attached hand operated mechanism that accepts rider inputs and converts into an electronic signal that is then directed to motor controller, which readjusts the voltage sent for BLDC hub motor. Throttle smooth out acceleration and makes the scooter quickly respond to speed demand changes. The design of the throttle is created to allow the user control in a comfortable way and manage the speed very easy. This improves the ride experience and also ensures safety as unexpected accelerations can be avoided.

Effective throttle control, motor performance, interface between rider and electrical system, its ergonomics, usability and safety are tightly connected to the overall usability of the product.

E. Arduino

Arduino Uno takes the data from sensors (ultrasonic sensors used for obstacle avoidance). It reads the sensor data in real time and control the actions by switching brakes on when it detects an obstacle. The board communicates with the motor controller for controlling speed and torque of the scooter on inputs received from throttle, while ensuring different modes. The board's digital and analogue I/O pins that allows easy connection of all types of things, coupled with the fact that it works well with a host of libraries and modules makes it quite developer-friendly. Finally, its miniature size and efficiency to consume minimum power and cost efficiency make it one of the appropriate options for an e-kick scooter. Arduino Uno also functions as the hub to all the hardware components, allowing for a seamless integration and operation of the scooter.

V. HARDWARE DESIGN

Designing an e-kick scooter involves a

multidisciplinary approach that integrates mechanical engineering, electrical engineering, and design principles to create a functional, efficient, and aesthetically pleasing personal transportation device. This process starts with conceptualizing the overall design, selecting appropriate components, and ensuring ergonomic and safety conside rations.

A. Motor Selection

Mass of the vehicle = 100 kg

Weight of the vehicle = (100 *9.81) N = 981 N

Speed of Vehicle = 25 km/h = 25*(5/18) = 6.944m/s (For Calculating Resistance due to motion)

Force due to climbing hills (F gradient) Fh = W sin Φ (Angle of incline Φ is 2.5)

= Mg sin Φ = 981x sin 2.5 = 42.79 N

Fr = Cr W cosΦ (for asphalt roads Cr=0.004)

= 0.004 x 981 x cos2.5 = 3.92 N

Air resistance: Fd = 0.5*ρ*Cd*A*V2

(Cd value is 0.5 for frontal area A=0.7 m2)

= 0.5 x (1.2) x 0.5 x 0.7x 6.9442 = 10.13 N

(ρ is density of air 1.2 kg/ m3)

Total Force on the Vehicle is, F = Fh+ Fr + Fd = 56.84 N Power required for propulsion, P = F*V

= 56.84*6.944= 394.7 Watts

Due to the unavailability of a 400-watt motor in the market, we opted for a 350-watt motor as a suitable and readily available alternative.

B. Battery Selection

Power rating: P = 350 W,

Battery voltage: V = 24V

Speed: V = 25 km/h = 6.944 m/s Range: 25 km

Calculations:

The energy required to be supplied by the battery per kilometre can be calculated as follows:

Wh/km = P/ Range = 350/25= 14 Wh/km

To supply this amount of energy, the capacity of the battery per kilometre should be

Ah/Km= 14/24 =0.58 Ah/hr

Hence, for the 25 km range, the capacity of the battery is: Ah= 0.58*25= 14.5 Ah

We have used a 24V, 12 Ah battery for powering the motor.

VI. RESULTS AND DISCUSSIONS

Electric kick scooter was successfully designed and has implemented all three main goals of efficiency, sustainability, and usability. The scooter performed well during testing with consistent operation across different operating conditions. The evaluation of the process showed that response to the throttle input is smooth and fast in terms of smooth acceleration and constant speed control by the vehicle. Moreover, the scooter is energy efficient in terms of its ability to travel about 25 kilometers distance covered per charge, which supports the idea of eco-friendly transportation. These results prove that the system is economical and suitable for sustainable urban commuting system.

Fig. 2: Implemented e-kick Scooter.

VII. CONCLUSION

An e-kick scooter with its embedded system is a first step towards smart urban transport. In this project, we have designed and built an

e-kick scooter with collision avoidance technology to ensure efficient and high performance. The resulting vehicle is robust and user friendly based on benchmarked standards of the existing models. The anti-collision system, which works via ultrasonic sensors offers an extra degree of protection for the riders. This added layer of protection significantly improves the scooter's reliability, making it a safe option for regular short-distance commuting.

The project also emphasize that technological solutions must be carried with good hands-on usability. Every component of the e-kick scooter aims at meeting the contemporary urban commuters needs, from component choice to ergonomic layout and host advanced features integration thoroughly.

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VITALMEDSYNC: AI-DRIVEN WORKFLOW AUTOMATION AND PERSONALIZED PATIENT CARE

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ABSTRACT

VITALMEDSYNC is an AI-driven healthcare platform designed to streamline clinical workflows by automating patient data management, enhancing communication, and providing in- telligent analysis. This platform includes services such as speaker segmentation and summary generation, which transcribe patient interactions and convert them into concise summaries for quick and efficient record-keeping. By enabling healthcare providers to access critical patient information at a glance, Vitalmedsync helps reduce the time spent on documentation. The platform also incorporates patient record summarization, which compiles and condenses a patient's history, allowing providers to quickly review essential details while minimizing information overload. Additionally, VITALMEDSYNC's chatbot service assists patients with common health-related queries, improving engagement and pro- viding timely information. Another key feature is the image analysis service, which evaluates prescription data and offers personalized dietary recommendations, ensuring that patients receive guidance tailored to their specific needs. Designed to reduce administrative burdens, improve data accessibility, and enhance patient support, VITALMEDSYNC empowers healthcare providers to focus more on delivering quality patient care.

Keywords—Electronic Health Records (EHRs), Natural Language Processing (NLP), Generative AI, Machine Learning Models

I. INTRODUCTION

Health care is one of the sectors that the world is still struggling to deliver efficient, precise, and timely medical care solutions even though technology in the medical field has developed significantly. There is inevitably a growing pressure on the higher patient inflow, mixed with the evolving nature of medical data and the discontinuity of clinical information exchange[1]. Some of the biggest concerns are related to docu- mentation and analysis of patient-doctor interactions, culling large number of records and lack of timely and direct patient care interventions outside the clinical setting [2]. These problems affect the quality of care, stall decision making, and add to the cognitive load of those in the healthcare sector.

Communication between a patient and a doctor in a tra- ditional care delivery model is still a slow and cumbersome affair that requires documenting every interchange. Client data is almost always recorded on paper and very often it is written down by the provider who might take large portions of it from memory, or use shorthand, thus losing valuable information and creating inconsistent notes [3]. This not only affects the clinical processes and makes them less efficient but also deprives patients of sufficient knowledge of their diagnosis or of the treatment to come. The absence of hierarchical and easy- to-search technical records also poses challenges on followups, which may in some cases take a long time before the next appointment as well as produce negative impacts on health status.

The keeping of medical records is another major challenge that has been identified as forming a major bottle neck. Healthcare professionals have to wade through large, complex patient data such as medical reports, patient records, and clinical documents to make decisions. It is time-consuming and can also be easily overlooked; thus, it takes a lot of time away from direct client contact. This exclusion also makes errors in diagnosis and treatment planning are more probable due to exhaustive analysis, which is framed in lengthy documentation, not properly synthesizing the patient's data—particularly dangerous in urgent healthcare scenarios [4].

Secondly, patients often have no easy access to immediate and trustworthy medical support outside of clinical spaces. Since they rely too much on scheduled consultations, tradtional models produce gaps in care, with patients missing out on addressing symptoms, sorting out doubts, or getting timely advice. As healthcare costs continue to climb, the lack of con- nection between patient experience and measurable outcomes continues to prevent healthcare quality improvement, increase patient dissatisfaction, and ultimately inhibit resolution of preventable health problems.

Artificial intelligence can play a game changing role in healthcare by improving efficiency across the ecosystem to address these systemic challenges. AI can handle documentation of patient-doctor interactions, accurately capturing conversations and allowing patients and providers to quickly see what was discussed [6]. Advanced AI systems can work with and analyze large amounts of medical records at any point, generating concise and precise summaries that enable providers to make better informed decisions.

These innovations have great potential to substantially im- prove healthcare delivery, reduce cognitive and administrative burdens on providers, and improve patient outcomes. Through AI to address these inefficiencies, healthcare can evolve into a more proactive and consumer-driven model, providing timely, accurate, and accessible care for everyone.

A. Organization of the Paper

The remainder of this paper is organized as follows. Section II reviews the related works in AI-driven healthcare, dis- cussing techniques from synthetic Electronic Health Record (EHR) generation to unsupervised pathology detection and summarizing key studies in Table I. Section III details the proposed system architecture, with its components illustrated in Figure 1. Section IV describes the machine learning models and datasets employed, including the methods used for speaker segmentation, chatbot training, and image analysis. Section V presents the training algorithms, including a Low-Rank Adaptation (LoRA) based fine-tuning approach for the chatbot and YOLO training on a dataset. Finally, Section VI discusses performance analysis and outlines potential directions for future research.

II. RELATED WORKS

Several studies have explored diverse aspects of AI-driven healthcare solutions. In one work, a synthetic EHR generation framework (SEHRG-DLD) [1] leverages Harris Hawks Opti- mization (HHO) and Deep Belief Networks to overcome data privacy challenges while ensuring high diagnostic accuracy. Another study [2] addresses clinical errors caused by acronym usage through word sense disambiguation (WSD) and Natural Language Processing (NLP) techniques, thereby enhancing diagnostic precision and preserving data privacy. Additionally, a system proposed in [3] integrates deep learning with layered visualization techniques to provide a comprehensive and intu- itive interpretation of complex medical conditions.

Other research efforts have focused on specific AI applications within healthcare. For instance, an AI-based medical chatbot [4] employs Natural Language Processing (NLP)

and Long Short-Term Memory (LSTM) networks for infectious disease prediction, underscoring the importance of extensive datasets and careful handling of language nuances. Similarly, a GAN-based multi-task learning framework for prognostics and health management (PHM) in Industrial Internet of Things (IIoT) is presented in [5], demon strating real-time prediction capabilities and improved fault data augmentation despite inherent training complexities. A study on large-scale medical record analysis [6] combines Bidirectional Long Short-Term Memory (BiLSTM) Network with a Transformer featuring multi-channel self-attention to deliver robust temporal model-ing, although it highlights the challenge of high computational overhead.

Broad frameworks aimed at enhancing the security, ex- plainability, and usability of AI in healthcare have also been developed. A federated learning solution [7] secures patient data privacy at scale, though it incurs significant communica- tion and computation overhead. A vision-language pre-training framework (IMITATE) [8] reduces annotation requirements by leveraging structured medical reports, albeit at the expense of extensive preprocessing. Furthermore, a human-centered methodology [9] emphasizes transparency, ethical alignment, and user trust, while requiring resource-intensive collaboration among stakeholders.

Recent studies have tackled challenges in disease trajec- tory forecasting, data security, and unsupervised pathology detection. A multi-agent Transformer model [10] predicts disease trajectories from multimodal data, thereby enhancing interpretability while imposing high computational resource demands. A global framework for Electronic Health Record (EHR) security and privacy [11] employs pseudonymization and blockchain technologies to safeguard sensitive informa- tion, although issues of scalability and maintenance remain. Finally, an unsupervised approach [12] that combines VAEs, GANs, and self-supervised models efficiently detects patho- logical anomalies, yet necessitates substantial maintenance and poses security challenges.

III. PROPOSED SYSTEM

VITALMEDSYNC is an innovative healthcare platform aimed at advancing the healthcare industry by integrating cutting-edge AI solutions within a mobile-first hospital man-agement system. As illustrated in Figure 1, the platform is designed for seamless use on mobile devices, delivering all the standard functionalities of a modern hospital management system while incorporating revolutionary AI modules to streamline clinical workflows, enhance communication between patients and healthcare providers, and improve overall decision-making.

TABLE I. TECHNIQUES, MERITS AND DEMERITS OF KEY AI-DRIVEN HEALTHCARE STUDIES

TITLE	TECHNIQUES	MERITS	DEMERITS
Leveraging AI-Generated [1] Content for Synthetic EHR Generation with Deep Learning -Based Diagnosis Model (Sayed Abdel-Khalek et al.)	SEHRG-DLD Model, Harris Hawks Optimization (HHO), Deep Belief Network, Golden Jackal Optimization	Improved Accuracy, Scalability, Context Sensitive	Data Scarcity, Imbalance in Datasets, Privacy Concerns
Clinical Errors [2] from Acronym Use in Electronic Health Records (Temitope Ibrahim Amosa et al.)	Word Sense Disambiguation (WSD) Algorithms, Natural Language Processing	Improved Diagnostic Performance, Privacy Preservation, Efficiency	Data Diversity, Ethical Constraints, Scalability
Humane Visual AI: Telling [3] the Stories Behind a Medical Condition (Wonyoung So et al.)	Bio-psycho-social Model, Deep Learning, Probabilistic Model, Layered Martini Glass Visualization	Holistic Approach, User-Friendly, High Impact	Complexity, Data Limitations
An AI -Based [4] Medical Chatbot Model for Infectious Disease Prediction (2022) (Sanjay Chakraborty et al.)	Artificial Intelligence (AI), Natural Language Processing (NLP), LSTM Algorithm (Deep Learning)	Predictive Accuracy, User-Friendly, Context-Aware, Always Available	High Data Needs, Language Nuances, Computational Cost, Model Complexity
GAN-Based [5] Multi-Task Learning Approach for Prognostics and Health Management of IIoT (Sourajith Behera et al.)	Generative Adversarial Networks (GAN), Multi -Task Learning (MTL), Gated Recurrent Unit (GRU)	Data Augmentation, Improved Accuracy, Resource Efficiency, Real-Time Prediction	Training Complexity, High Resource Demand, Model Instability
Large-Scale [6] Medical Records Analysis Driven by AI Method in Healthcare Consumer Electronics (Xin Wang et al.)	Bidirectional LSTM (BiLSTM), Transformer with Multi-Channel Self-Attention (MCSA)	Temporal Modeling, Global Attention, Enhanced Robustness, Improved Generalization	Complex Implementation, High Computational Cost, Data Dependency
Federated Learning [7] for Medical Applications: A Taxonomy, Current Trends, Challenges, and Future Research Directions (Ashish Rauniyar et al.)	Artificial Intelligence (AI), Edge Computing, Federated Learning (FL), Large Language Model (LLM)	Privacy in Sensitive Data, Enhances Model Generalization, Integrates Blockchain for Security	High Communication or Computation Costs, Vulnerable to Data Inference Attacks, Limited to Regulated Sectors
IMITATE: Clinical [8] Prior Guided Hierarchical Vision-Language Pre-training (Che Liu et al.)	Self-Supervised Learning, Vision-Language Pretraining, Data Annotation and Labeling	Outperforms in Multiple Medical Tasks, Requires Less Annotated Data, Better Generalization	Depends on Structured Medical Reports, Expensive Pre-processing, Slower Development Process
Designing AI [9] Using a Human-Centered Approach: Explainability and Accuracy Toward Trustworthiness (Jordan Richard Schoenherr et al.)	Distributed Cognitive Systems, Computational Auditing, AI Governance	Promotes Transparency and User Trust, Multi-Stakeholder Collaboration, Ethical Alignment	Limits Full Automation Potential, Resource-Intensive Interdisciplinary Collaboration
Clinically Inspired [10] Multi-Agent Transformers for Disease Trajectory Forecasting From Multimodal Data (Huy Hoang Nguyen et al.)	Transformers, Multi-Model Integration, CNNs (Convolutional Neural Networks)	Accurate Forecasting, Multi-Model Processing, Calibrated Predictions, Interpretability	High Computational Cost, Complexity, Data Dependency
A Global Medical [11] Data Security and Privacy Preserving Standards Identification Framework (Vinaytosh Mishra et al.)	Pseudonymization, Blockchain Technology, Machine Learning	Prioritization, Comprehensive Interoperability, Flexibility	Scalability Issues, Complexity, Cost, Technical Barriers, Maintenance
Unsupervised Pathology [12] Detection: A Deep Dive Into the State of the Art (Ioannis Lagogiannis et al.)	Unsupervised Learning, Deep Learning, Self-Supervised Learning	Increased Efficiency, Real-Time Monitoring, Faster Decision-Making, Reduced Manual Effort	Security Risks, High Initial Costs, Maintenance Complexity, Limited Human Interaction

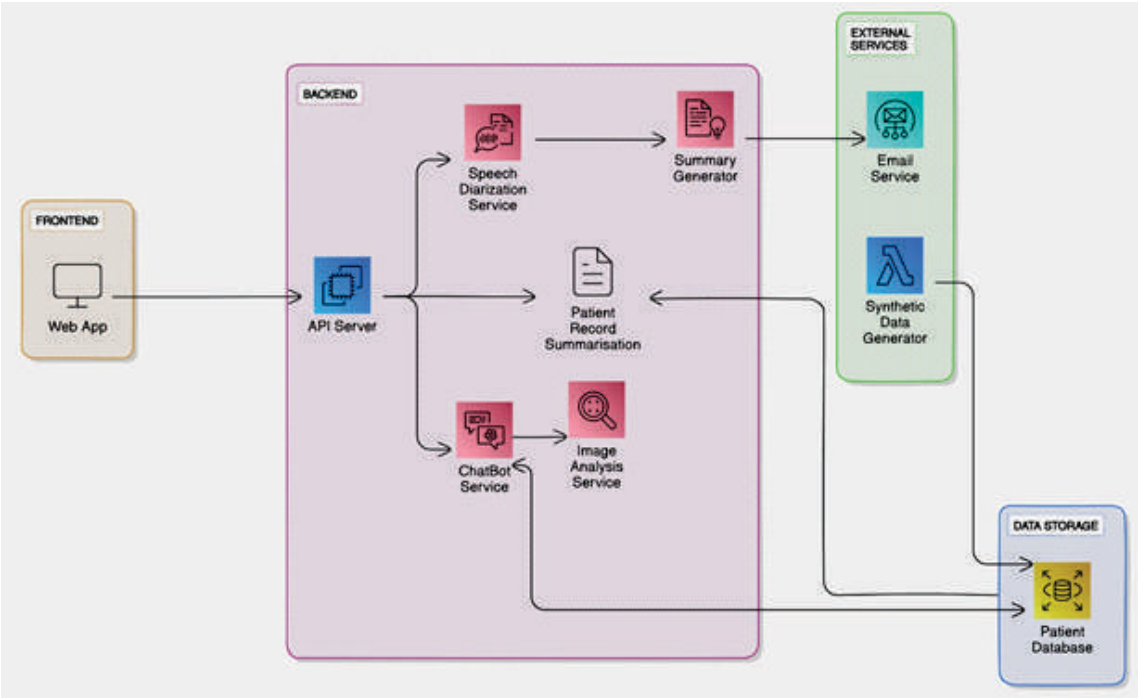

Fig. 1: VITALMEDSYNC Architecture Diagram

At the core of VITALMEDSYNC is an advanced speaker segmentation system that accurately distinguishes between the voices of patients and doctors during consultations. This module leverages state-of-the-art speech datasets that capture diverse and realistic conversational scenarios and integrates doctor-uploaded voice samples to ensure precise speaker iden- tification.

Another major component is the AI-powered chatbot that employs Retrieval-Augmented Generation (RAG) technology. This model is designed for easy fine-tuning and efficient adaptation to domain-specific tasks, empowering it with a persistent memory of previous conversations and patient history for context-aware responses.

Complementing the speech and conversation modules is an image analysis component based on a YOLO model, designed for tasks such as calorie estimation and handwritten prescription recognition. The classification outputs from the YOLO model are fed directly into the fine-tuned chatbot, enhancing its ability to generate accurate and context-aware answers.

The backend architecture of VITAL MEDSYNC is built using modern server-side frameworks and robust database so- lutions, ensuring high performance and scalable data management- ment. Additionally, the system adheres to strict data protection standards (e.g., HIPAA), securing sensitive medical information through robust encryption and authentication mechanisms. This ensures that patient data remains private and can be accessed safely on mobile devices without compromising integrity. Furthermore, the platform seamlessly integrates with existing EHR systems to minimize disruptions during data migration.

Overall, the integration of advanced AI models with a robust backend infrastructure enables

VITALMEDSYNC to deliver precise predictive analytics, efficient documentation, and personalized patient care—a significant leap forward in applying AI to modern healthcare challenges.

IV. MACHINE LEARNING MODEL

A. Datasets

- Domain-Specific Datasets for Speaker Segmentation: Datasets such as the AMI Meeting Corpus [13], AISHELL-4 [14], and AliMeeting [15] facilitate accurate speaker segmentation by providing diverse conversation samples.
- Chatbot Training Datasets: The ruslanmv/ai-medical- chatbot dataset (approximately 257,000 interactions) [17] and the MedDialog dataset [18] are used to fine-tune the TinyLlama model for generating context-aware medical conversations.
- Image Analysis Datasets: Curated datasets for food calo- rie estimation [19] and handwritten prescription recogni- tion [20] serve as the training basis for the YOLO model.

B.Models

- Speaker Segmentation: The system utilizes PyAn- note.audio [23] combined with OpenAI Whisper [24] to effectively segment and transcribe patient–doctor conversations. The integration of doctor-uploaded voice samples enhances voice similarity analysis, leading to improved speaker identification.
- Chatbot: Developed upon the pre-trained TinyLlama model [21], the chatbot is fine-tuned using the medical dialogue datasets referenced above. The model is recog- nized for its ease of fine-tuning and efficient adaptation to specialized medical conversation tasks.
- Image Analysis: A YOLO model [22] is employed to classify visual data for tasks such as calorie estimation and handwritten prescription recognition. The classifica- tion outputs from the YOLO model are fed directly into the chatbot to enhance its ability to generate accurate, context-aware responses.
- Data Summarization: The fine-tuned TinyLlama model

[21] is further utilized to generate concise summaries of patient interactions and historical data, enabling health- care professionals to quickly review essential information and make informed decisions.

V. CHATBOT TRAINING ALGORITHM USING LORA FINE-TUNING AND YOLO TRAINING ALGORITHM

A. Algorithm 1 Chatbot Training via LoRA Fine-Tuning

1: Input: Pre-trained TinyLlama model M (4-bit quan- tized), medical dialogue dataset D, LoRA hyperparam- eters (r, α, p), training parameters (batch size, epochs, learning rate)

2: Output: Fine-tuned model Mft and merged model Mmerged for inference

3: Install required libraries and authenticate with Hugging Face Hub.

4: Load pre-trained TinyLlama model with 4-bit quantiza- tion.

5: Load tokenizer.

6: Load medical dialogue dataset D.

7: Format dataset as: "### Patient Query: [instruction]\n### Doctor Response:\ n[output]".

8: Tokenize dataset with padding and truncation.

9: Configure LoRA with parameters: r = 16, α = 32, dropout p = 0.1.

10: Apply LoRA to target modules {”q proj”, ”v proj”}.

11: Freeze base model weights; set LoRA parameters as trainable.

12: Define training arguments (batch size,

learning rate, epochs).

13: Initialize Trainer and train model Mft.

14: Save fine-tuned model Mft and tokenizer.

15: Reload base model M and LoRA adapter.

16: Merge LoRA adapters: Mmerged, model. merge_and_unload().

17: Save merged model Mmerged for deployment. =0

B. Algorithm 2 YOLO Training on Roboflow Dataset

1: Input: YOLO model architecture A, Roboflow dataset D (images & annotations), training parameters (batch size, epochs, learning rate), optional pretrained weights

2: Output: Trained YOLO model M

3: Set up the environment, install libraries, and extract D into proper directories.

4: Load and preprocess images and annotations, applying data augmentation.

5: Initialize model M with architecture A and load pretrained weights if available.

6: Define loss function L (localization, confidence, classification) and initialize the optimizer.

7: for epoch = 1 to epochs do

8: Set M to training mode.

9: for each minibatch (X, Y) in the training set do

10: Compute predictions Yˆ = M (X) and loss l = L(Yˆ, Y).

11: Backpropagate and update M via the optimizer.

12: end for

13: Evaluate M on the validation set; save checkpoint if performance improves.

14: end for

15: Save the final trained model M for deployment. =0

VI. PERFORMANCE ANALYSIS

The performance of the medical prescription analysis model is assessed using key metrics, including loss functions, preci- sion, recall, and mean average precision (mAP). These met- rics evaluate the model's effectiveness in extracting medicine names from handwritten prescriptions. Loss curves track optimization, while precision and recall measure accuracy and completeness of detections. The mAP scores further quantify performance, with mAP@0.5 reflecting localization accuracy at a high intersection-over-union (IoU) threshold, and mAP@0.5:0.95 offering a stricter assessment.

Handwriting variations, irregular spacing, and medical ab- breviations pose challenges in prescription analysis. Many prescriptions contain overlapping strokes, inconsistent letter formations, and visually similar medicine names, increasing classification difficulty. These factors demand robust text de- tection techniques for accurate extraction.

As shown in Figure 2, the training and validation loss curves demonstrate a steady decline, indicating stable con- vergence. The box loss progressively decreases, confirming improved bounding box localization for text regions. Similarly, the object detection confidence loss follows a downward trend, reflecting increased confidence in detecting relevant handwrit- ten text. Classification loss drops sharply in the early stages before stabilizing, signifying the model's ability to distinguish between different medicine names. The validation losses ex-hibit a similar pattern to the training losses, reinforcing the model's generalization capability and absence of overfitting.

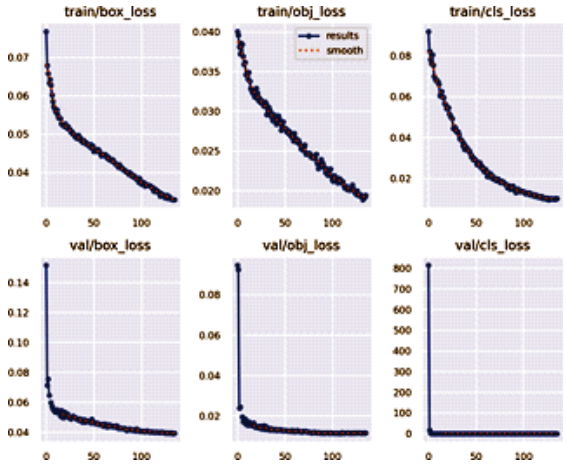

Fig. 2: Training and Validation Loss Curves for Box Loss, Objectness Loss, and Classification Loss

Evaluation metrics further validate the model's effectiveness. As illustrated in Figure 3, precision stabilizes after initial fluctuations, demonstrating improved bounding box predictions. Recall steadily increases, ultimately reaching an approximate value of 0.38, which highlights the model's ability to retrieve relevant medical terms despite variations in handwriting. The mAP@0.5 score stabilizes around 0.4, while the stricter mAP@0.5:0.95 score reaches 0.3, confirming robust text detection across different IoU thresholds.

While these results confirm the model's ability to process medical prescriptions effectively, further improvements can be achieved through data augmentation with diverse handwriting styles, enhanced preprocessing techniques to reduce noise, and hyperparameter tuning. These refinements have the potential to enhance precision, recall, and mAP scores, ultimately improving the accuracy of medical text extraction.

VII. CONCLUSION

VITALMEDSYNC offers a revolutionary solution to the significant challenges faced in today's healthcare landscape. By leveraging cutting-edge technologies like machine learning, natural language processing, and real-time data analytics, the platform streamlines clinical workflows, promotes effective communication between patients and providers, and encour- ages patients to take an active role in their healthcare journey. The use of a variety of datasets, including both real-world and synthetic data, guarantees thorough model training and allows the system to provide precise predictions, automate doc- umentation, and enhance preventive care. VITALMEDSYNC prioritizes data security and compliance, ensuring that sen- sitive patient information is protected in line with global healthcare standards.

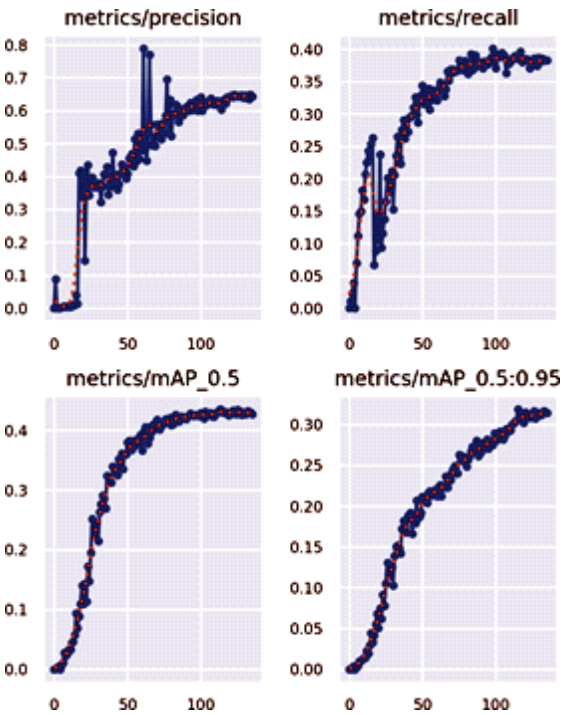

Fig. 3: Precision, Recall and Mean Average Precision (Map) Performance Metrics.

As a versatile and responsive platform,

VITALMEDSYNC has the potential to revolutionize healthcare delivery by alleviating administrative burdens, enhancing diagnostic accuracy, and promoting improved health outcomes. Its innovative strat- egy sets the stage for a more intelligent, efficient, and patient- focused healthcare ecosystem.

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ADVANCING GAME DEVELOPMENT AND SIMULATION WITH UNITY 3D: INTEGRATION OF PROCEDURAL CONTENT GENERATION, GENETIC ALGORITHMS, AND IMMERSIVE LEARNING EXPERIENCES

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ABSTRACT

Unity 3D has become a leading platform in the game development industry, known for its cross platform capabilities, flexibility, and real time rendering tools. The integration of Procedural Content Generation (PCG) and Genetic Algorithms (GA) has emerged as a revolutionary advancement in game design, automating content generation and optimizing object placement across complex environments. This paper explores the combined power of these methodologies and their application in Unity 3D to create dynamic simulations, interactive educational games, and immersive storytelling experiences, through an in-depth study of various game development projects, including driving simulators, interactive narratives, and dynamic object placements. This paper highlights how these integrated technologies streamline the game development process, ensuring scalability, increased player engagement, and educational value. By utilizing the Game Development Life Cycle (GDLC) methodology, the paper also addresses key challenges faced during development, such as optimization, asset management, and platform compatibility. Case studies illustrate the benefits of using PCG and GA in complex scenarios, from irregular level layouts to multi-object scattering, offering insights into their real world applications.

Keywords: Unity 3D, Genetic Algorithm, Procedural Content Generation, Game Development, Educational Games, Virtual Reality, Game Design

I. INTRODUCTION

Unity 3D has appeared to dominate the game development industry, specifically addressing flexibility, real time rendering, and cross platform support [1]. Besides these advancements in games, the inclusion of advanced techniques such as Pro- cedural Content Generation (PCG) and Genetic Algorithms (GA) is very important since it optimizes content and provides dynamic and entertaining gameplay. Thus, this article applies PCG and GA in Unity 3D projects and brings the methodolo- gies together into GDLC to make the user experiences more interesting. The research also emphasizes the integration of methodologies within driving simulators, educational, and narrative-based interactive games.

II. LITERATURE SURVEY

A. Unity 3D in Game Development

Unity 3D is considered the most versatile and widely used engine for game development with multi-platform compatibil- ity. It allows the development of 2D and 3D games and real time physics simulations and has a large asset store to speed up the development process. Unity is unique in building im- mersive experiences within story driven and interactive games, utilizing real time rendering coupled with a very extensive asset management system [2], [3]. The versatility of Unity lets developers concentrate on the creative sides of the game development process, leaving the technical problems to the components furnished by the engine itself.

B. Procedural Content Generation (PCG)

and Genetic Algo- rithms (GA)

The primary method for automating content generating pro- cedures and enhancing game designs is, of course, PCG, which has particular utility in creating large and diverse game worlds or levels in an automated fashion. This makes it suitable for open world or rogue like environments spanning environments that instantiate GA according to the steps involved in object distribution. Methods for optimizing game objects placed in levels will ensure that GA's placement methods of objects are compatible and collective throughout. After the population has been introduced, it will be evaluated.

The purpose of the fitness function is to maximize the distance between objects contending for the search, while minimizing the variance and slot occupancy in order to avoid clustering. GA optimizes object placement across model level designs through mutational and selection operations. Contin- uous Application of GA to object scattering [4], optimizes the placement of game elements, producing engaging game-play from level designs with unusual complexity. Separate regions with stark differences present outstanding challenges for standard content placement, yet they illustrate GA's ability to handle these complexities. It ensures that the objects will be uniformly diffused while still accepting randomness, which is an essential factor in making gameplay captivating.

This technique was particularly effective when GA was applied to achieving optimal object distribution over irregular levels, such as those containing narrow passages and disconnected areas. These irregular levels present additional challenges for standard content placement, but the GA method demonstrated its ability to tackle these complexities, ensuring even distribution of objects while maintaining the randomness essential for engaging gameplay. A prime example that arose from the cases applied to irregular levels and several object common types (NPCs, obstacles and collectibles) showed how GAs balanced object placement, making for varied and unpre- dictable scenarios, subsequently complementing the gaming experience.

C. Educational and Simulation Game Design

Unity's role in educational games extends beyond enter- tainment, providing interactive environments for skill building. For instance, driving simulators mimic real world conditions, helping users overcome anxiety in virtual spaces [5] . Unity's ability to simulate dynamic interactions like traffic and pedes- trian movements makes it ideal for these applications [6].

D. Interactivity in Unity-based Games

Interactivity is a fundamental aspect of many games created within Unity. Real time scripting in Unity permits responsive gameplay wherein actions of the player affect the state of the game world instantly [7]. Unity's C# scripting allows developers to create complex interactions; for example, sim-ple AI behaviors, player inputs, and environmental inter- play. Interactive elements like dynamic NPCs, puzzle solving mechanisms, and real time decision making keep a player interested. Complex interactions between objects allow for more immersion and reactiveness because of the interplay of other interactive elements, such as the Unity AI toolset and Physics Engine.

E. Challenges in Game Development and Testing

Although there are numerous advantages to using Unity 3D, PCG, and GA, a few obstacles remain during the development process. One of the major issues lit up by various studies, is balancing gameplay mechanics, which keep the player engaged and yet allow realism. Further optimization arises as another serious

challenge. While managing large scale assets and complex scenes, ensuring smooth performance across diverse hardware is a big hurdle across the board [8],[9]. This becomes further pronounced when assets are from different sources, including external 3D models, audio, and textures. In such cases, one has to be careful while integrating entities to avoid compatibilities or disruption of the game's performance. The area of testing also brings in a number of other challenges. Game testing presents challenges, particularly in managing complex interactive systems and real time behaviors. Black Box testing and User Experience Questionnaires (UEQs), normally need few iterations to ensure that game features suffice player's expectations and work properly.

III. METHODOLOGY

A. Game Development Life Cycle (GDLC)

Game Development Life Cycle (GDLC) is the guiding process throughout the development of all projects considered in this project. The model works on the principle that games should be developed through phases that are systematic so as to limit errors and improve productivity [10].

- Initiation: Conceptualization of the game's storyline, me- chanics, and objectives.
- Design: Creation of the Game Design Document (GDD), which includes detailed descriptions of gameplay me- chanics, levels, art style, and assets.
- Production: Asset creation, modeling, and development using C# for scripting gameplay logic, Conducting Black Box Testing and User Experience Questionnaires (UEQ) to assess functionality and player engagement.
- Release: Final product release after refining the game based on testing results.

B. Tools and Technologies

The key tools and technologies used for game development and simulation include:

- Unity 3D: The core engine for game creation, supporting cross platform deployment and real time rendering.
- Unreal Engine: Another powerful option for Unity is that provides immense graphic power and simulation support and creates complex environments and is among the best in rendering fidelity.
- C# : The scripting language used for implementing game mechanics and interactions, primarily within Unity[11].
- Blender and Maya: These tools are used for 3D modeling and animation of assets like characters, objects, and environments
- Genetic Algorithms (GA): Used for object placement optimization and procedural content generation.
- Physics Engine: Integral for simulating realistic interac- tions between game objects, vehicles, and the environment.

IV. RESULTS AND DISCUSSION

A. Key Features and Achievements

Unity has been important in the success of various projects including, but not limited to, driving simulators and educa- tional games. For example, Genetic Algorithms were applied to object scattering driving simulators to create a dynamic environment in which objects were arranged evenly and op- timally, presenting a balanced and engaging experience for players [12]. In addition, Unity's easy real-time rendering and elements of interactivity were helpful in developing immersive environments replicating real world scenarios.

B. Development Challenges

The main challenges encountered during the development process included:

- Optimization: Ensuring smooth performance across dif- ferent hardware platforms, especially with complex 3D environments.

• Asset Integration: Managing and integrating assets from external platforms like the Unity Asset Store and GitHub while maintaining compatibility with the Unity engine.

• Balancing Realism and Fun: In simulations like driving games, educational simulations etc., striking the right balance between realism and enjoyable gameplay were essential for user engagement.

V. CONCLUSION

The development of games in Unity 3D integrated with Procedural Content Generation and Genetic Algorithms offers a solid state of development. This integration allows the creation of rich, scalable, and interactive game environments. Even with the challenges of optimization and asset management, Unity's flexibility combined with the potentials of GA and PCG puts more interactive simulations and educative experiences within everyone's reach. The subsequent work focuses on improving the approach of the algorithm in dealing with irregular layouts, parameter tuning, and multi-platform optimization.

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A REVIEW ON AIR FLOW AND AIR DRAG CHARGING IN EVS

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ABSTRACT

This study aims to better understand the aerodynamic darg forces generated in conventional cars and electric cars I n general and the possibility of producing energy from air flow generated by an EV when in motion. Various research on this topic is reviewed in this paper to further understand the concept of using Dynamic Air Flow Charging as a method to increase the energy usage in EVs and to increase its operational time. The paper focuses on the effects of introducing a wind turbine system to generate energy from the air flow produced, and it effectiveness when placed at different ends of a moving vehicle. Its effects when placed in the front end and rear end of a car are reviewed experimentally and by software simulations to provide a clear picture into energy lost to gained patterns while in operation. Pre-existing car models are used in simulation and experiments. The effects of using this system under braking conditions were also studied through experiments. Simulations were conducted using SolidWorks, ANSYS FLUENT, PTC Creo and AUTODESK FLOW DESIGN. Drag forces acting on the car, its drag coefficient with the wind turbine systems were found and boundary conditions were set to stimulate a real-world environment to get the results.

Keywords: DAC, EV, air flow aerodynamics, drag force drag coefficient

I. INTRODUCTION

There are a few different approaches to air flow-based charging of EVs, but one common approach involves using a device called a "dynamic air charger" (DAC). A DAC is a small device that is mounted on the front or rear of an EV and uses the motion of the air to generate electricity. The DAC typically consists of a turbine or a series of blades that are mounted on a shaft and are driven by the movement of the air. As the blades rotate, they generate electricity that can be used to charge the batteries of the EV. There are several potential benefits to air flow-based charging of EVs. One benefit is that it can potentially extend the range of an EV by providing a source of continuous charging while the vehicle is in motion. This could be especially useful for long trips or for EVs that are used in areas with limited access to charging stations. Additionally, air flow-based charging could potentially reduce the need for heavy and expensive battery packs, since the vehicle could potentially rely more on DAC for its electricity needs. However, it is important to note that air flow-based charging is still in the early stages of development and is not yet widely available. There are also some challenges that need to be addressed, such as the cost and efficiency of DACs and the potential impact on the aerodynamics of the vehicle. As a result, it is not yet clear how widely air flow-based charging will be adopted in the future.

II. EV AERODYNAMICS

In a car normally 50% of the drag force is caused by the upper body of the car, in the wheel 25% and the rest from the lower body. However, in an electric vehicle a flat under body panel is used. This results in reduced drag force generation. Though flat

underbodies create less drag forces more studies are being conducted to further reduce this drag force creating a more aerodynamic design. In a conventional car design the underbody has many pipis extensions and engine parts which are the cause of increased drag. For the bottom section of an EV this is not present and only the battery is located at the bottom which rest flat on the surface. A study conducted by Ishihara (Ishihara 2019) showed the different types of under body panel results for better aerodynamic performance of the car. Some of the panels studied are shown in the fig. 1

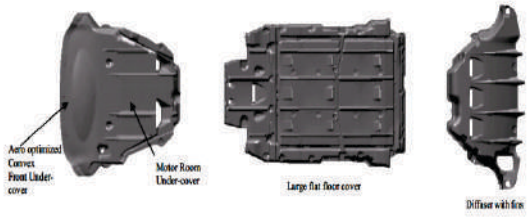

Fig.1: Under Body Panels of Nissan Leaf

III. DACS AT DIFFERENT CAR SECTIONS

The application of DACs in different sections of the car result in varying energy generation patterns. This paper focuses on applications of DAC systems fixed at the front, upper body and rear end of an electric vehicle to produce energy. These systems create energy loss due to the system weight and air drag created inside the system these losses and drag patterns are also discussed below.

A. Turbine is Placed Infront of the Car

The possibility of incorporating airflow charging system infront of a vehicle to improve energy management is discussed in [1]. This is tested using ANSYS- FLUENT. The car is set to travel at a speed of 27m/s for a distance of 100 km. different CAD models of the vehicle were created using SolidWorks to get a better understanding on energy loss to gain patterns. Three variations of the model are tested to provide a better understanding of airflow patterns and energy gains.

For the analysis shear stress transport k-ω model was used. The SST k-ω model which was proposed in 1994 by mentor is used to tackle limitations of k-ω and k-Є models. They create an unreliability of damping functions when applied in variety of flows. Here the sensitivity to high free stream values of ω at the inlet and limited flow separation in smooth surface is due to very high wall shear stress. And therefore it gives us a better prediction.

(a) (b) ©

Fig.2: Different Car Models M0, M1, M2

The M0 model shown in Fig 2 is the base model with front bumper panel and grills. The M1 model was made by drilling a circular duct of 510 mm diameter at front as shown in fig.2 b. the M2 model was designed by adding a pre-existing turbine to the drilled hole in M1 model.

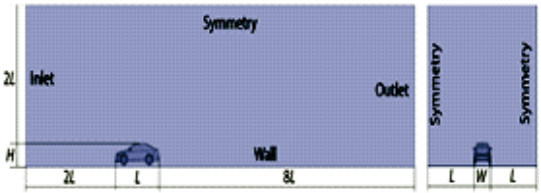

Fig.3: Domain Under Consideration

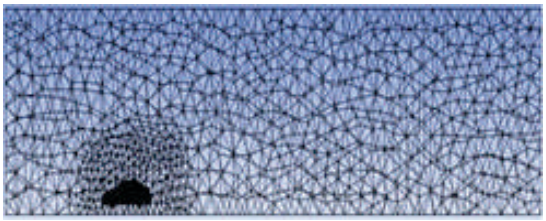

Fig.4: Mesh Patterns

The turbine used is a horizontal axis wind turbine with a rating of 500 W and a speed range of 0 to 27 m/s. for the study, study of smaller elements as shown in fig.2 were used

for the region were effect of drag coefficient are examined. For more accurate study the surface of the car was split in three triangular sections and an additional grid independence study was also conducted. During the grid independence study, it was found out that the drag coefficients converged at 67254 nodes and 3749698 sections. The mesh of the domain is shown in fig 4.

1) Results obtained from simulation

Table 1 given below shows the result of the simulation.

TABLE 1. RESULTS OBTAINED FROM SIMULATION

Model	Max Pressure	Drag coefficient Cd	Aerodynamic loss
M0	452.2 Pa	0.2814	37443.3 kJ
M1	472.7 Pa	0.3053	40623.4 kJ
M2	460.7 Pa	0.2928	38960.2 kJ

The figure given below shows the aerodynamic energy consumed and the energy gain by different models.

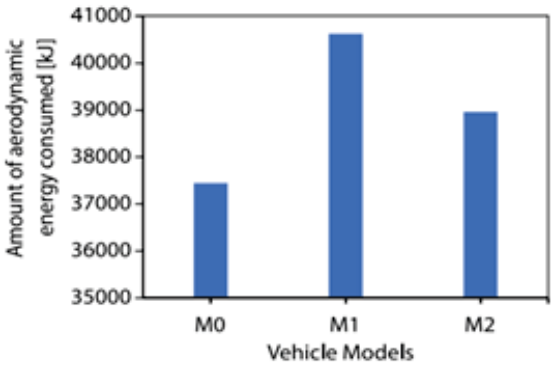

Fig.5: Aerodynamic Energy Consumed by Different Models

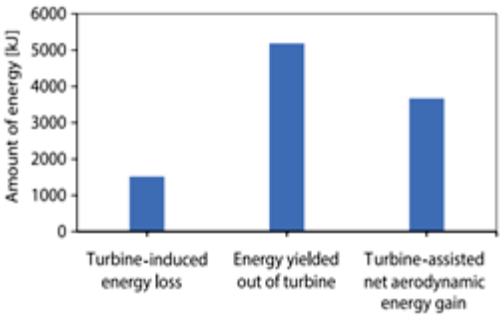

Fig.6: Energy Gain to Loss Graph of M2 Model

For the M2 model the energy yielded form the turbine was calculated using eq. (1) and eq. (2).

$$Ptur = 1/2\ \rho AV\ 3CP \qquad (1)$$

$$E(J) = P(W) \times t(s) \qquad (2)$$

The energy lost between base model M0 and the turbine model was found to be 1685.44 KJ and energy gained from the wind turbine was 3499.80 KJ. The energy lost, energy gained from the turbine and net energy gain achieved from the turbine system are shown in fig.5. Energy lost and gained percentage for base model and model with the turbine system are calculated using eq. (3) and eq. (4)

$$\%Loss = Eturbine\ induced\ loss\ /\ Ebase\ model \qquad (3)$$

$$\%Gain = Eturbine\ assisted\ gain\ /\ Ebase\ model \qquad (4)$$

From the equation it was observed that energy loss percentage was about 2.4%, while the energy gained from the wind turbine system was 5.41%. From the calculations it was observed that during the span of 100 km the energy lost due to the turbine was considerably less compared to the energy gained from the turbine itself.

B. Turbine Placed at the Rear End of the Car

Energy gain patterns and scope of DAC when wind turbine systems are placed at the rear end of the car is shown in [2]. Both CFD

simulations and experiments were conducted. The authors have conducted the experiment on 1998 Honda Accord LX to evaluate the possibility of using micro wind turbines to generate energy from moving cars.

AUTODESK FLOW DESIGN was used to conduct the CFD analysis and PTC Creo was used to create the solid model. This model was meshed in the software within a wind tunnel environment and boundary conditions were set to find the drag force generated during motion. The experiments were conducted with wind speeds of 35.6m/s and the car moving at a speed of 80mph. The results obtained were experimentally tested with and without the turbine. Cruise control was turned on to maintain constant speed from 30 mph to 80mph, multiple test runs were performed with identical fuel composition and speed.

The wind turbines for the experiment were tested separately in a controlled environment to map their performance. The turbines were fitted with Hall Effect sensors to measure turbine rpm during motion. During the initial test, speed was set from 0 to 20 m/s this gave a peak voltage of 30V from the turbines. Later load conditions were introduced by increasing circuit resistance.

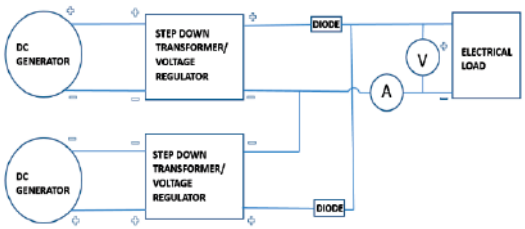

Fig.7: Control Circuit

1) Results obtained from simulation

The drag force and drag coefficient from the simulations are given in table 2. It was observed that there was a slight decrease in Cd when wind turbines were added.

TABLE 2. RESULTS OBTAINED FROM SIMULATION

Parameter	With wind turbine	Without wind turbine
Drag force (N)	585.5	798.8
Coefficient of drag	3.9	4.7

Fig. 7 given below shows the variations in the wind velocity with respect to the car speed.

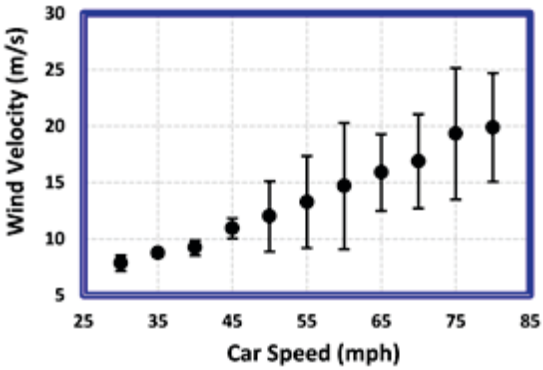

Fig.7: Variation in Turbine Speed with Varying Car Speed

The graph at fig. 8 shows fluctuations in wind velocities which can be attributed to varying cross wind flow, gush of local wind or wind generated from other moving bodies through the set route.

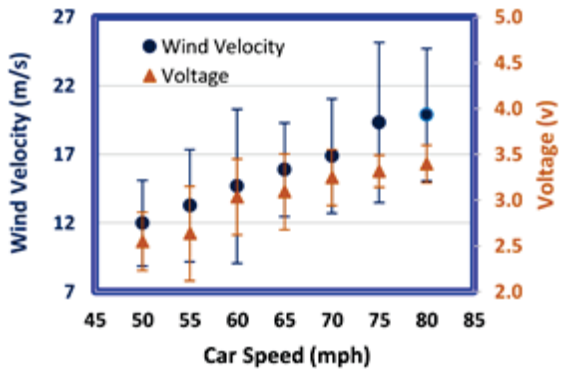

Fig.8: Voltages Generated with Respect to Wind Velocity and Car Speed

Despite these fluctuations a stable wind car velocity relation was established for testing as shown in fig 7. It shows the variation of turbine

speed for car speeds and the speeds of both turbines are almost similar to each other. The experiments revealed that at 50mph the turbine system generates voltage of 2.5V and gradually increases with wind speeds, as the car reaches speed of 80mph it is observed that the power generation starts to saturate. This is caused by the voltage controllers integrated into the system. Here fluctuation patterns are due to the limitations set in the voltage.

$$Power = Voltage \times Current \qquad (3)$$

C. Air Drag Charging

In this method drag force created during breaking is used to run a wind turbine system to produce power[3]. The system is fitted at front end of the car for maximum efficiency.

Parameter	With wind turbine	Without wind turbine
Drag force (N)	585.5	798.8
Coefficient of drag	3.9	4.7

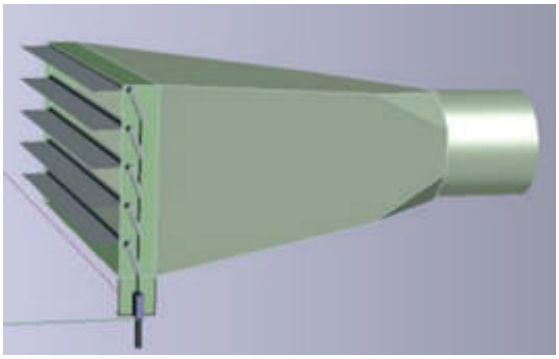

Fig.9: Air Inlet of the System

The flaps remain closed when the car is in a state of motion, when breaks are applied the flaps open which lets the wind pass in. In this system since the flap remains closed during motion the drag force of turbine operation is removed and during breaking the drag force devolped in the turbines result in a faster stop. From the experiments conducted it showed an output voltage of 12V. This observation points to the future application of air drag charging in cars.

IV. CONCLUSION

In the current energy scenario creating more energy efficient and sustainable transport systems are necessary. From the studies conducted above, it can be inferred that DAC systems are cable of delivering cost effective energy. The main limitation that came up in the current technology is that the car or any vehicle employing these systems must attain a speed higher than 80mph to produce energy that outweigh the loss produced due to the system. It is also observed that as the speed of the vehicle reaches 80mph the energy produced also saturates and so as speed increases the energy output does not increase proportionally. This can be attributed to the turbine efficiency and electric circuits of the system. Overall, these systems provide us a solution for better energy management in the future.

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SOUNZ : SOCIAL PLATFORM FOR MUSIC COLLABORATION

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ABSTRACT

Collaboration is key in today's music industry, where artists, producers, and musicians work together to create innovative compositions. This music collaboration platform facilitates seamless teamwork by offering real-time communication, project management, and cloud-based audio file sharing. Equipped with multi-track editing, live collaboration features ,it connects artists across the globe. Its intuitive interface and integration with popular digital audio workstations streamline the creative process. By eliminating geographical constraints, the platform enhances collaboration, enabling musicians to produce high-quality music efficiently in a digitally connected environment.

Keywords: Django, Python, Music collaboration Social platform

I. INTRODUCTION

A music collaboration social platform serves as a digital hub where musicians, producers, and creators can connect, exchange ideas, and work together effortlessly. It incorporates key features like real-time multi-user editing and cloud-based file to help artists find suitable collaborators. Instant notifications ensure users stay informed about project updates and new partnership requests, while a responsive interface guarantees seamless access across various devices. Built-in chat and messaging functions facilitate smooth communication, removing the need for third-party apps. By optimizing the creative workflow and nurturing a connected music community, this platform enhances collaboration and streamlines the music production process.

II. RELATED WORKS

Facebook, Twitter, and other social networks handle an excessive amount of data. Users may find it challenging to locate the information that is most important to them as these platforms get bigger. A customized recommendation system that displays content to users based on their connections within the social network and their individual interests is the proposed solution. The system distributes popular posts across the network using a popularity diffusion model, and it employs tailored techniques to guarantee that users see the most pertinent content. To ensure that it keeps functioning properly as the social network expands and changes, the system also has effective algorithms to manage network changes. In terms of speed and user-friendliness, tests conducted on both real and simulated data demonstrate that this approach performs better than other methods.[1]

We can learn more about society and the beliefs, habits, and interests of its members by using social media. It presents a web application that allows users to categorize posts by creating custom categories and to follow particular Facebook accounts. With the help of these posts, the app creates reports and statistics that display the topics of discussion in real time. In addition to helping businesses monitor social media comments

about their products, this tool is helpful for individuals looking to learn more about society [2].

Facebook serves is a prime example of the technology that powers social networks. While millions of users engage with the platform daily, many remain unaware of its underlying operations. The system is divided into two main components: the frontend, which encompasses the visual design, buttons, and interactive features users engage with, and the backend, which functions behind the scenes to manage data storage, user accounts, and post processing. Facebook's backend relies on technologies such as PHP and MySQL, whereas its frontend is built using languages like HTML, CSS, and JavaScript [3,4].

Scores are essential for writing and performing music compositions. Despite the abundance of tools available, collaborative and communication functionalities are frequently absent from music score creation tools. When sharing their work and interacting with others, musicians typically use social media sites like Facebook and Instagram. Therefore, Music is a brand-new social network created especially for musicians to interact and exchange knowledge [5].

Collaborative work is becoming increasingly important in technology-enhanced music training. By utilizing tools for synchronized playback and recording, it facilitates the process of establishing groups and classes. A flexible system that can handle various group roles and tools is required to support this. In order to facilitate the creation and administration of cooperative music lessons, it offers a flexible system. The instrument was created for the European Commission-funded IMAESTRO STREP FP6 project, which aims to construct instruments for group music instruction. For music notation, the system adheres to a standard format to guarantee interoperability with other tools.[6,7]

In order to compare a social network of musicians to other intricate web networks, the paper analyzes this particular network. It examines the relationships between various musical data points and how network theory fits these relationships. The community structure of the artist network is then examined by the paper using hybrid graphs and -distance measures. The results demonstrate that these various methods outcomes are largely independent of one another. It also discusses on how recommendation and discovery applications could benefit from the use of these hybrid measures.[8]

Through the use of a chat program individuals can have direct online conversations. Users are able to communicate with each other through messaging. WeChat WhatsApp QQ Mobile and Facebook Messenger are a few well-known examples. We want to develop a web-based chat application that is accessible from anywhere in the world. Both the frontend and backend will be built using Firebase and ReactJS. Both iOS and Android will support this application. [9,10]

The study examines the factors that contribute to social collaboration tools value for smart commerce. It concludes that features like price design security and ease of use are crucial to consumers .It lists efficient methods for promoting these tools online via email social media blogs official websites and search engines. The study also makes recommendations for the most beneficial features and marketing strategies based on the age gender and type of business of the target audience.[11,12]

Websites must be made to function properly across all platforms not just computers since more and more people are accessing the internet through smartphones and tablets. This is made possible by responsive web design which ensures that a website works well on all devices by adjusting to various

screen sizes and resolutions. It looks at how device usage trends are currently affecting web browsing and mobile commerce (m-commerce). It examines the benefits of responsive web design like enhanced accessibility and usability as well as possible drawbacks like more development time or technical difficulties.[13,14]

Finding products is becoming more difficult as online shopping takes off because there are now a lot of websites selling a large variety of goods. It suggests a new method to monitor and comprehend product searches in order to facilitate the process. The method entails looking at the word combinations that people type into search engines. The technique determines the amount of information that each search word offers by examining historical search data. It then models how users look for products using this data. This technique is a helpful tool for enhancing search functions on shopping websites as the study discovered that it successfully monitors and anticipates user behavior when searching for products.[15]

III. PROPOSED METHOD

A. Overview

SOUNZ is a dynamic social platform designed to facilitate seamless music collaboration by connecting musicians, producers, and creators worldwide. This enables real-time collaboration with multiple users and cloud-based file sharing, helping artists connect with the right collaborators. Instant notifications keep users informed about project updates, messages, and partnership requests. Its responsive interface ensures smooth access across all devices, while built-in chat and messaging features enable effective communication. SOUNZ also includes customizable project workspaces, integration with digital audio workstations , and a thriving community for networking and creative inspiration. By simplifying the collaborative process, SOUNZ fosters an engaging and efficient environment for music creation

B. Architecture and Technology Stack

SOUNZ features a visually appealing and adaptable front end built with HTML, CSS, and JavaScript, ensuring seamless accessibility across desktops, tablets, and mobile devices without compromising functionality or aesthetics. The user-friendly interface prioritizes ease of navigation, making every feature easily accessible. On the backend, Django, a robust Python web framework, manages server-side operations, user authentication, and database interactions, providing scalability and security to accommodate a growing user base while ensuring data privacy. For database management, SOUNZ utilizes SQLite to efficiently store and organize user data, posts, and media files, enabling smooth data retrieval and management. The platform's design emphasizes innovation and responsiveness, incorporating modern UI/UX principles to create an intuitive and visually engaging experience. From user registration to content uploads, every aspect is designed for simplicity and efficiency, ensuring a seamless experience across all devices.

C. Key Features of SOUNZ

1) Collaboration

The collaboration functionality of SOUNZ is one of its best features. Through a straightforward and user-friendly process, users can express interest in working with other artists. The collaborate button allows users to send an email request to the post owner when they come across a post on which they would like to work together. The collaboration request is described in this email, which uses a premade 'SOUNZ' template. It also includes the user's username. This feature strengthens the platform's collaborative nature by encouraging networking and group creative endeavors.

2) Notification

The notification feature in a music collaboration social platform keeps users informed about key updates and interactions in real time. It notifies them of new collaboration invitations, project progress, messages, comments, and other important activities, improving engagement and workflow. Users can personalize their notification settings to receive timely alerts without unnecessary interruptions. Whether through in-app notifications, emails, or push alerts, this feature ensures that musicians, producers, and creators stay connected and communicate effortlessly throughout the collaboration process

3) Responsive

The responsive website feature in a music collaboration social platform allows users to access and interact with the platform smoothly on any device, from desktops to mobile phones. It dynamically adapts to different screen sizes, preserving usability and aesthetics. With optimized layouts and an intuitive design, users experience easy navigation and consistent functionality. This adaptability ensures that musicians, producers, and creators can collaborate efficiently without technical limitations, making the platform more user-friendly and accessible.

4) Chat application

A chat application within a music collaboration social platform facilitates smooth and instant communication among artists, producers, and creators. It supports real-time messaging, file exchanges, and group conversations, improving teamwork and creative discussions. Since it is built into the platform, there's no need for third-party messaging apps, making the workflow more efficient. With functionalities like notifications and multimedia sharing, users can easily collaborate and stay engaged throughout their projects

5) Media visibility

Media visibility control in a music collaboration social platform empowers users to regulate access to their uploaded content. With adjustable privacy settings, creators can choose to share their media publicly, restrict it to selected collaborators, or keep it private. This feature enhances security and content management, allowing musicians and producers to maintain control over their work while promoting a secure and collaborative space.

6) Search and explore page

The search and explore page in a music collaboration platform enables users to find artists, projects, and content effortlessly. Using smart filters , it allows users to discover potential collaborators based on genre, expertise, or geographical location. This feature strengthens networking by helping musicians, producers, and creators connect while also showcasing trending and relevant content to inspire new collaborations.

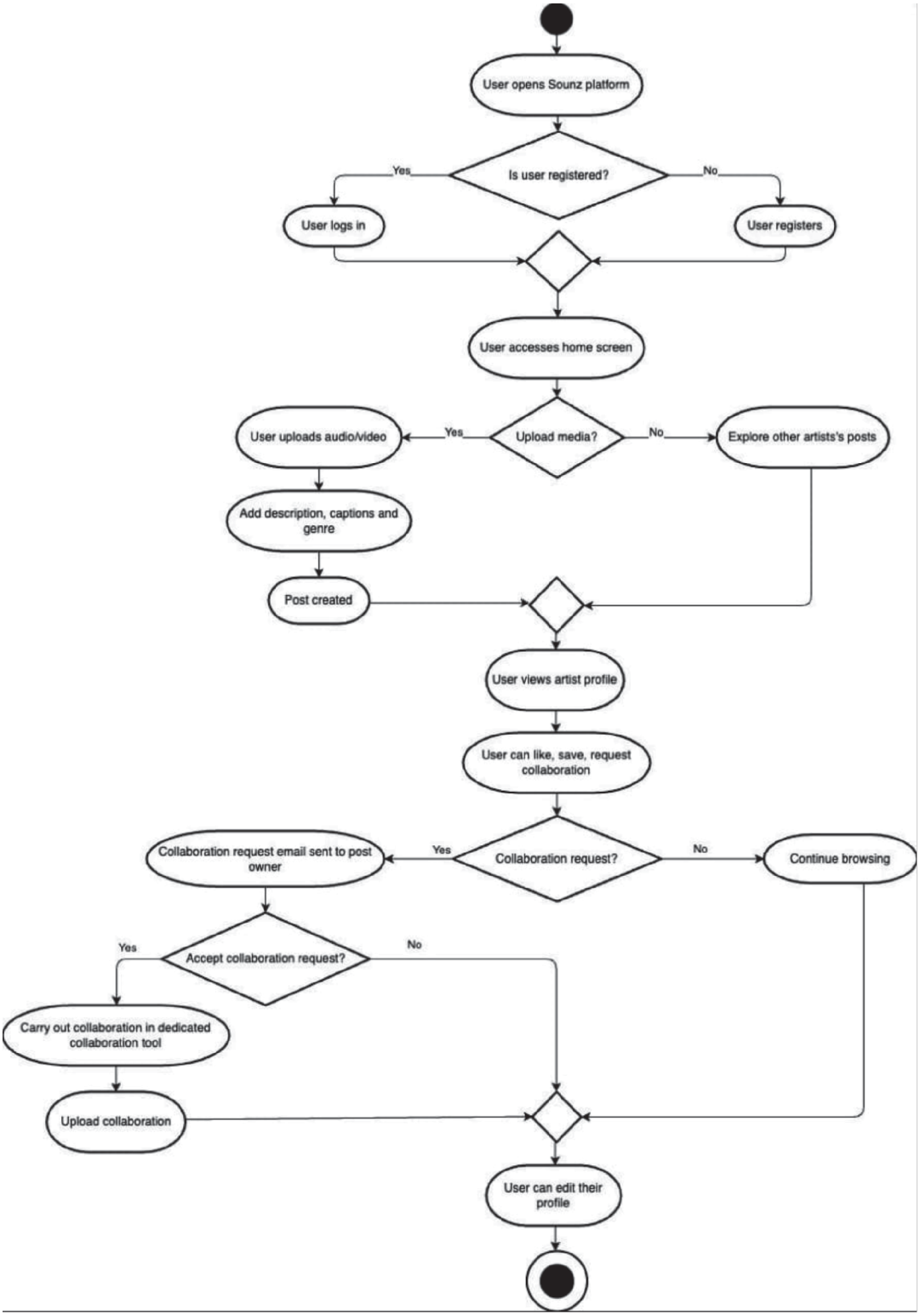

Fig. 1: Architectural Design

7) Content reporting

The content reporting feature in a music collaboration platform enables users to report inappropriate, harmful, or unauthorized material. This helps maintain a respectful and secure community by allowing moderators to review and address flagged content. With an easy-to-use reporting system, users contribute to platform safety, ensuring a professional and positive space for creative collaboration.

8) Copyright reporting

SOUNZ uses an audio fingerprinting-based copyright identification system to detect potential copyright violations. When a user uploads an audio file, the system generates a unique fingerprint using MFCC-based audio comparison. If a copyright claim is reported, the uploaded audio is compared against pre-existing compositions using raw audio data hashing to check for similarities. This ensures fair use protection while maintaining a collaborative environment for artists.

9) Like and unlike

The like/unlike feature in a music collaboration platform enables users to show support for content shared by artists, producers, and creators. Liking a post boosts engagement and provides creators with valuable feedback, while the option to unlike ensures users can adjust their interactions. This feature fosters community involvement and helps artists understand audience preferences.

10) Post save

The save feature in a music collaboration platform lets users store or bookmark content for future reference. It helps artists, producers, and creators keep track of significant projects, favorite posts, or inspiring materials without the hassle of searching again. By offering a dedicated space for saved items, this feature improves organization, streamlining workflow and creative management.

11) Edit and delete

Post editing and deletion features in a music collaboration platform empower users to manage their shared content effectively. The edit option lets musicians, producers, and creators update their posts, fix mistakes, or add new information without needing to repost. On the other hand, the delete function allows users to remove posts that are outdated or unnecessary. These tools provide greater flexibility, ensure content remains accurate, and contribute to a smoother user experience.

12) Follow and unfollow

The follow and unfollow feature in a music collaboration platform helps users connect with artists, producers, and creators while keeping track of their latest content and activities. Following someone ensures regular updates, promoting interaction and networking, while the unfollow option allows users to refine their feed and control their engagement. This feature enhances customization, enabling users to focus on relevant collaborations and content that align with their interests.

IV. ALGORITHM

A.Algorithm for Mixing Multiple Audio Files :

Input:

- A base audio file
- Multiple user-uploaded audio files

Output:

- A mixed audio file in MP3 format, uploaded to the server

Step 1: Fetch Audio Files

1. Retrieve the list of user-uploaded audio file URLs.
2. Append these URLs to a predefined base audio file URL.
3. If the total number of audio files is less than 2, terminate the process.

Step 2: Load and Decode Audio Files

4. Load each audio file and decode it into an

audio buffer.

5. If fewer than 2 files are successfully decoded, terminate the process.

Step 3: Determine Mixing Parameters

6. Find the maximum duration among all the decoded audio buffers.

7. Create an empty audio buffer with:

• 2 channels (stereo)

• Length based on the maximum duration

•Sample rate matching the original buffers

Step 4: Mix Audio Buffers

8. For each decoded buffer:

• Iterate through each audio channel (left/right).

•Retrieve the corresponding channel data.

•Sum the sample values of the decoded buffer into the mixed buffer.

Step 5: Normalize Mixed Audio

9 . Identify the maximum amplitude in the mixed buffer.

10. If the amplitude exceeds 1, scale all values proportionally to normalize the audio.

Step 6: Convert to MP3 Format

11 Convert the final mixed buffer into an MP3 audio file.

Step 7: Upload Mixed Audio

12. Upload the MP3 file to the Django backend for storage and processing.

B. Algorithm for Copyright Detection in Audio Posts

Input:

• Two audio files: user-submitted audio and reported audio

• Threshold value for similarity comparison

Output:

• A JSON response indicating whether a copyright violation is detected

• If a violation is found, the reported post is flagged and a notification is sent

Step 1: Validate Request

1. Accept a POST request for copyright reporting.

2. Retrieve reported post id and user post id from the request.

3. If either ID is missing, return an error response (400 Bad Request).

4. Fetch the reported post and user's post from the database.

Step 2: Extract MFCC Features for Audio Comparison

5. Load both audio files using librosa.

6. Extract MFCC features from each file.

7. Compute the Euclidean distance between the MFCC feature vectors.

8. If the distance is below the threshold, consider it a match.

Step 3: Handle Copyright Violation

9. If the audio files match:

• Retrieve the timestamps of both posts.

• If the reported post is newer than the user's post

• Flag the reported post (set flagged = 1).

• Save changes to the database.

Step 4: Send Notification (If Flagged)

10. Identify the owner of the reported post.

11. Create a notification for the flagged user:

• Sender: User who reported the violation.

• Recipient: Owner of the flagged post.

• Message: "Your post has been flagged for copyright infringement."

12. If an error occurs while sending the notification, log the error.

Step 5: Return JSON Response

13. If the post was flagged, return:

•"match": True, "flagged": True, "message": "Copyright violation detected!"

14. If the match is found but the reported post is older, return:

•"match": True, "flagged": False, "message": "Match found, but original post is newer."

15. If no match is found, return:

•"match": False, "flagged": False, "message": "No copyright violation detected."

V. CONCLUSION

In summary, SOUNZ is a revolutionary

platform that redefines the way musicians, producers, and creators collaborate in the digital era. By integrating advanced features such as real-time multi-user editing and cloud-based file sharing, it creates an interactive and engaging workspace where artists can seamlessly connect and work together. One of its key advantage is eliminating geographical constraints, allowing users from different parts of the world to collaborate on music projects without limitations. The platform's intuitive and responsive interface ensures smooth navigation and accessibility across various devices, making it convenient for users to engage with their projects anytime, anywhere. Additionally, SOUNZ enhances workflow efficiency by offering instant notifications, built-in chat functionality, and secure media visibility controls, ensuring that artists remain connected and updated throughout the creative process. Its structured approach to project management allows users to efficiently organize their work, track progress, and collaborate in a structured manner. The platform's backend, powered by Django and SQLite, ensures data security, scalability, and seamless performance, making it reliable for both individual creators and large-scale collaborations.

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VR CHATBOT WITH CHATGPT API INTEGRATION: TECHNIQUES AND TRENDS

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ABSTRACT

Virtual reality technology has revolutionized user interactions by offering immersive environments, transforming various industries such as education, healthcare, and entertainment. This project presents a virtual reality chatbot system integrated with the ChatGPT API to enhance user experiences in virtual spaces through intelligent, context-aware conversational capabilities. The VR Chatbot takes advantage of the natural language processing capabilities of ChatGPT to enable seamless interactions within a 3D virtual environment. By embedding conversational AI in VR, users can engage in human-like dialogues for various purposes, including education, customer service, and virtual training. The system is designed to understand user intents, provide dynamic responses, and support multiturn conversations, thus creating an interactive and immersive user experience. The integration of the ChatGPT API ensures scalability and flexibility, allowing the VR chatbot to cater to diverse domains with minimal customization. The project incorporates features such as speech-to-text and text-to- speech conversion, ensuring accessibility for users with varying preferences. Furthermore, the VR interface is optimized for intuitive navigation and contextual relevance, improving over- all usability and engagement. This system demonstrates the potential of combining VR with advanced conversational AI to create innovative solutions for virtual communication and problemsolving. Applications include virtual customer support, language learning, healthcare consultations, and personalized virtual assistants. Future enhancements may include emotional sentiment analysis and integration with IoT devices for more advanced functionalities.

Keywords: Virtual Reality, ChatGPT API, Chatbot.

I. INTRODUCTION

VR has revolutionized user interactions by creating immersive, interactive environments for applications in education, healthcare, gaming, and customer service. However, traditional input methods like menus and pre-scripted dialogues limit the effectiveness of user communication within VR spaces. To address this,we introduce a VR Chatbot integrated with the ChatGPT API, combining immersive VR capabilities with advanced conversational AI.

The VR Chatbot enables natural, human-like communication through dynamic, multiturn conversations powered by ChatGPT's state-of-the-art natural language processing (NLP). This allows users to interact seamlessly with virtual environments via text or voice-based input, receiving contextually relevant and intelligent responses. Applications range from virtual tutors in education and customer support in retail to healthcare assistants for consultations, making the system versatile and adaptable. Key features include speech-

to-text and text-to-speech functionality for accessibility, intuitive VR interfaces for ease of navigation, and the scalability of the ChatGPT API for customization across various industries. By bridging the gap between VR and AI-driven interactions, the system enhances user engagement, creating a more intuitive and immersive experience. This project demonstrates the po- tential of combining VR with conversational AI to transform virtual communication and problem solving. It provides a foundation for future advancements, such as sentiment analysis and real-time IoT integration, paving the way for innovative, intelligent VR solutions that redefine user interaction in digital spaces.

II. RELATED WORKS

The integration of conversational AI into immersive environments like Virtual Reality (VR) has been a growing area of interest in recent years. Several studies and projects have explored the combination of Natural Language Processing (NLP), 3D environments, and human-computer interaction to create more intuitive and engaging virtual experiences.

1)Chatbots in Virtual Reality Environments : Initial efforts to build chatbots for VR environments largely relied on rule-based or scripted responses. These systems were often used in training simulations, museum tours, or virtual assistance setups where user interaction was limited to a predefined set of inputs. For example, in virtual training applications for emergency response, chatbots played roles of victims or instructors. [1] However, these bots struggled with handling unexpected inputs and lacked the flexibility of real conversations. Similarly, platforms like Second Life and IMVU had early implementations of chatbots using simple AI scripts (e.g., AIML), but these could not offer deep or contextual engagement. The static nature of these early bots highlighted the need for intelligent, adaptive conversation systems paving the way for integration with advanced NLP models like ChatGPT.

2) Use of NLP and AI in Chatbots [2] : The evolution of Natural Language Processing has been a significant milestone in the development of conversational agents. Traditional approaches such as keyword matching or rule-based logic have been replaced by neural language models like BERT, GPT-3, and GPT-4, which provide contextual understanding, emotional tone detection, and intent recognition. One study titled “AI Chatbots for Educational VR: A New Frontier” demonstrated the use of NLP models in virtual classrooms, where students could ask questions and receive contextually relevant answers from an AI tutor. The chatbot improved student participation and learning outcomes compared to static learning resources. With the advent of transformer-based models, responses are generated based on the user’s intent and the ongoing conversation history. This capability enables highly personalized and human-like interactions, which are critical in VR environments where immersion and realism are priorities.

TABLE I. TECHNIQUES, MERITS AND DEMERITS BASED ON SURVEY

TITLE	TECHNIQUES	MERITS	DEMERITS
Text-based VR Chatbots	- Simple chatbots integrated into VR environments, offering basic interactions.	- Easy to implement, cost-effective, and can provide basic information.	- Lack of context awareness, limited engagement, and artificial interactions.
Game Engine-Specific Scripts	- Chatbots integrated into specific game engines, providing limited functionality.	- Easy integration with game engines and potential for performance optimizations.	- Limited cross-platform compatibility, restricted functionality, and potential performance issues.
Toward VR in VR Assessing Engagement and Social Interaction in a Virtual Conference	- XR integrates virtual and real-world environments, creating immersive ed - ucational experiences for remote and interactive learning.	- XR enhances student engagement by providing im - mersive and interactive experiences that simulate real -world environments.	- High costs and the need for specialized hardware like VR headsets limit its widespread adoption.

3) Integration of GPT APIs in Applications [3] : The release of the OpenAI ChatGPT API has significantly expanded the potential for developers to integrate advanced conversational capabilities into a wide range of applications. This includes customer support bots capable of resolving user queries in real time, mental health chatbots that offer empathetic dialogue for emotional support, and intelligent game NPCs (Non-Playable Characters) that engage players through dynamic interactions. However, despite these successful implementations, most integra tions have been limited to traditional 2D platforms such as web interfaces and mobile applications. The incorporation of ChatGPT into Virtual Reality (VR) environments remains relatively new and presents unique technical challenges. These include accurate speech-to- text conversion for voice-based inputs, real-time response generation to maintain immersion, and managing latency to ensure seamless communication. None theless, experimental projects like AI Dungeon in VR and community-created modifications in VRChat have demonstrated the feasibility of using GPT- based models to power conversational VR avatars. These early efforts suggest growing interest and highlight the potential for creating more immersive, interactive, and intelligent virtual experiences.

4) VR Platforms and Avatars with Conversational AI

Modern VR platforms such as Meta Horizon Worlds, AltspaceVR, and VRChat have introduced avatars with varying levels of AI capabilities, allowing for more immersive and interactive user experiences. Some of these avatars can respond to basic voice inputs or trigger predefined animations based on specific phrases, laying the foundation for more dynamic conversational agents. Notably, initiatives like Project Lifelike Avatars by Meta (Facebook Reality Labs) explore how expressive, AI-driven speech in avatars can enhance social presence and realism in virtual environments. Additionally, independent developers have experimented with integrating ChatGPT-powered NPCs into VRChat, enabling users to engage in open-ended, context-aware conversations with virtual characters. While these advancements highlight the growing potential of combining VR with conversational AI, there are still notable limitations, including a lack of personalization, minimal memory retention across sessions, and limited environmental awareness, such as recognizing and interacting with surrounding virtual objects. These challenges present opportunities for future improvements and innovation in creating more intelligent and responsive virtual agents [4].

5) Human-Computer Interaction in Immersive Environments: A key area of research relevant to VR chatbots is Human Computer Interaction (HCI) within immersive environments, where users naturally expect interaction methods to mirror real-world behavior favoring voice commands, gestures, or eye gaze over traditional input devices like keyboards or controllers. Numerous HCI studies have demonstrated that voice-based interfaces significantly enhance user engagement and reduce cognitive load in VR applications. Conversational agents in these settings can function as virtual companions, tutors, or guides, making VR experiences more intuitive and inclusive, especially for non-technical users. Furthermore, emotionally intelligent AI responses have been shown to improve user satisfaction by enhancing the sense of presence and empathy within the virtual space. A notable example lies in therapy-focused VR applications, where patients interact with AI avatars for purposes like exposure therapy or man- aging social anxiety; these avatars dynamically adjust their tone and content based on real-time user behavior, closely mimicking human-like interactions. Integrating ChatGPT into such

HCI frameworks enables the development of responsive, emotionally aware, and highly interactive VR agents that can significantly elevate the realism and utility of virtual environments. [5]

III. PROPOSED SYSTEM

The proposed system enhances virtual learning through an immersive VR environment, AI-powered virtual assistants, and a robust backend infrastructure. The system simulates an educational institution where users interact with subject-specific AI teachers, providing an engaging and interactive learning experience. The architecture of the proposed system, shown in Fig. 1, illustrates how the VR Chatbot system functions and how its different components interact. The system consists of three main components:

1) Virtual Reality Environment (Unity/Unreal Engine)

[6]: The virtual environment serves as the primary interface for users to engage with AI-driven learning. It offers an immersive and interactive educational experience with:

- 3D Educational Institution: Realistic classrooms, lecture halls, and interactive areas.
- Navigation Controls: Users can explore using VR headsets, controllers, or keyboard/mouse.
- Interactive Elements: Virtual objects like books, charts, and whiteboards enhance the learning experience.

2) AI-Powered Virtual Assistants (ChatGPT API) [7]: The AI assistants function as subject-specific teachers, re- sponding dynamically to user queries and providing realtime guidance. Key functionalities include:

- Natural Language Processing: AI understands and responds to voice and text inputs.
- Subject-Specific Assistance: Bots specializing in Math, Science, History, and other disciplines.
- Visual Learning Aids: Ability to display charts, simulations, and videos.
- Adaptive Learning: Personalized responses based on user progress and learning patterns.

3) Backend System (Cloud Services, APIs): The backend infrastructure supports user management, AI interactions, and data analytics, ensuring seamless system operation. It includes:

- User Authentication: Secure login using Firebase, AWS Cognito, or other authentication services.
- Data Management: Stores user interactions, progress tracking, and learning history.
- AI Processing: Integrates with the ChatGPT API for natural language understanding and response generation.
- Analytics Dashboard: Monitors system performance and user engagement metrics.

As shown in Fig. 1, these components work together through secure APIs, ensuring a seamless experience for users while promoting responsible waste management and recycling.

A. Key Features and Functionalities

1) AI-Powered Chat Support:

- Offers real-time assistance through AI-driven virtual assistants.
- Allows follow-up questions and contextual understanding.

2) User Interaction Engagement:

- Voice and text-based communication.
- Gesture-based controls.

3) Immersive Virtual Environment:

- 3D-modeled classrooms, lecture halls, and interactive areas
- Supports VR headsets, controllers, and

traditional

navigation

B. System Benefits

1) Immersive Learning Experience:

- Enhances user engagement through VR-based

interactivity.

- Provides a realistic simulation of a classroom

environment.

2) Seamless User Experience:

- Designed for easy navigation with intuitive UI/UX.

- Provides smooth interaction between VR, AI, and backend systems.

3) Scalability Expansion:

- Supports multiple subjects and adaptable to different education levels.

- Can integrate AR elements for blended learning experiences.

- Designed for future expansion to corporate training and professional certifications.

4) Enhanced Collaboration Engagement:

- Encourages student discussions and peer-to-peer learning.

- Fosters an interactive and dynamic learning community.

C. System Overview

The VR chatbot system integrates ChatGPT into a virtual reality environment, enabling immersive and interactive conversations. Designed for applications in healthcare, education, customer service, and general assistance, it allows users to communicate through voice, text, and gestures, enhancing engagement and accessibility.

The system consists of several components. The VR environment serves as the primary interface where users interact using a VR headset and controllers. A 3D avatar, such as a MetaHuman or a custom model, represents the chatbot, creating a lifelike presence. Users can communicate via a virtual keyboard or through speech recognition, making interactions more natural.

ChatGPT handles natural language processing, ensuring responses are contextually relevant. Conversational history is maintained to provide continuity. Custom prompts and fine- tuning allow the chatbot to be tailored to specific domains like healthcare or education.

Speech processing enables seamless voice interactions. Automatic Speech Recognition (ASR) converts spoken input into text, while Text-to-Speech (TTS) generates realistic voice responses, making conversations feel more dynamic.

The backend system, powered by Unity or Unreal Engine, manages VR interactions and UI rendering. An API server (built with Node.js or Python using Flask/FastAPI) connects the VR environment to ChatGPT, processing user data and handling queries. A database such as Firestore or PostgreSQL stores conversation history, user preferences, and logs for analytics and personalization.

Additional integrations include sentiment analysis for detecting user emotions, multi-language support for global accessibility, and animation systems for dynamic avatar responses. The chatbot can be enhanced with real-time facial tracking, allowing expressions to sync with speech. Cloud services like OpenAI's API ensure scalability, while edge computing optimizes real-time performance. Security measures such as end to end encryption and user authentication protect interactions. The chatbot can be deployed in standalone VR applications or integrated into multiplayer virtual spaces, enabling group interactions.

IV. PERFORMANCE ANALYSIS

The VR chatbot integrated with the ChatGPT API has been assessed against conventional customer support methods and alternative AI-driven chatbot solutions. The evaluation emphasizes the efficiency, engagement, and adaptability improvements introduced by this intelligent virtual assistant.

1) Conversational AI vs. Traditional Support Systems: Traditional support systems rely on scripted responses, limiting flexibility in handling diverse user queries. In contrast, the VR chatbot leverages ChatGPT's natural language processing capabilities, enabling it to understand and generate dynamic responses, improving user experience and reducing reliance on human intervention.

2) Immersive User Interaction and Engagement [8]: Unlike conventional chatbots that operate through

text based interfaces, the VR chatbot provides an immersive environment where users can interact with a virtual AI assistant. This enhances engagement by enabling:

- Real-time voice and gesture-based communication
- Interactive 3D avatar responses
- Context-aware assistance based on user behavior

This immersive interaction fosters more intuitive and effective conversations, improving user satisfaction.

3) Context Awareness and Adaptive Responses:

Traditional chatbots often lack contextual memory, leading to fragmented conver sations. The VR chatbot, powered by ChatGPT API, integrates session-based memory, allowing it to:

- Retaining context within ongoing interactions
- Adjust responses based on user history
- Offer personalized recommendations

This results in more coherent and adaptive conversations tailored to individual users.

4) Sentiment Analysis for Enhanced User Experience [9]: Unlike static AI chatbots, the VR chatbot incorporates AI driven sentiment analysis to detect user emotions and adjust responses accordingly. This feature helps in:

- Identifying user frustration or satisfaction levels
- Modulating tone and response style
- Providing empathetic and contextually appropriate interactions

By adapting to user sentiment, the chatbot improves overall engagement and response effectiveness.

5) Scalability and Customization: Traditional support systems require extensive manual setup and maintenance. The VR chatbot is designed with scalability in mind, enabling:

- Easy adaptation for various industries (e.g., healthcare, education, retail)
- Integration with additional AI services for enhanced functionality
- Seamless updates and customization based on organizational needs

This ensures a flexible and future-proof solution for VR-based interactions.

6) Multimodal Interaction Capabilities: Unlike standard AI chatbots, which primarily rely on text or voice input, the VR chatbot supports multimodal interactions, including:

- Voice recognition for hands-free operation
- Gesture-based commands for intuitive navigation
- Environmental awareness for contextual responses

This enhances accessibility and provides a more interactive and lifelike user experience.

7) Security and Privacy Considerations: Data security is a critical concern for AI-driven chatbots. The VR chatbot incorporates robust security measures, including:

- End-to-end encryption for secure communication
- Compliance with data privacy regulations
- Customizable access controls to safeguard user interactions

These measures ensure a secure and trustworthy virtual assistant experience.

8) Impact on Productivity and Efficiency: By automating support and reducing the need for human intervention, the VR chatbot enhances productivity by:

- Handling high volumes of inquiries simultaneously
- Reducing wait times for user assistance
- Allowing human agents to focus on complex queries

This results in improved efficiency and cost savings for organizations deploying the chatbot. The VR chatbot with ChatGPT API integration represents a significant advancement in virtual assistance, providing a highly interactive, intelligent, and scalable solution for modern communication and support systems.

V. CONCLUSION

The VR Chatbot with ChatGPT is more than just a virtual assistant. It is a comprehensive AI-driven conversational ecosystem. By integrating natural language processing, sentiment analysis, and immersive interaction, the chatbot enhances user engagement and efficiency in various applications. Unlike conventional systems, this chatbot is designed to improve user satisfaction by offering dynamic, engaging, and context- aware conversations. It fosters a more natural interaction by understanding user behavior and emotions, leading to better support and engagement.

With its scalable and adaptable architecture, the VR Chatbot with ChatGPT sets a new standard for virtual assistance. By leveraging AI, immersive technology, and interactive features, this project envisions a future where virtual interactions are seamless, personali zed, and intelligent. Through innovation and continuous improvement, individuals and organizations can benefit from an AI-driven assistant that enhances productivity and communication in an engaging virtual space.

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