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- To develop qualities of technology incubation, entrepreneurship and research orientation among students.
- To support the sustainable development of society through continuous student centric activities and functioning of professional bodies.

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AI-Based Plant Recognition And Care System

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***Abstract*—The decline of traditional agricultural practices due to urbanization has led to a growing need for innovative solutions to promote sustainable plant care. Many individuals perceive plant care as a daunting task, requiring extensive knowledge and expertise. To address this issue, an artificial intelligence-based system has been developed to empower individuals to grow plants with ease. Utilizing computer vision and a Convolutional Neural Network (CNN) model, the system accurately identifies plant species and provides tailored recommendations for optimal growth. By analyzing images, the model determines the specific type of plant and offers personalized care guidelines, including water frequency, manual application, and sunlight requirements. This AI-driven solution enables individuals to overcome common challenges and successfully cultivate their own plants, promoting sustainable living and reviving the tradition of home gardening. With its user-friendly interface and accessibility features, the system has the potential to make a significant impact on the way individuals approach plant care, fostering environmental resilience and promoting a healthier lifestyle. By bridging the gap between technology and sustainable living, this system can have a lasting impact on individuals and communities.**

***Index Terms*—AI-based plant recognition, plant care system, computer vision, plant identification, sustainable plant care.**

I. INTRODUCTION

India is one of the largest agricultural producers globally, with farming being a significant contributor to the country's economy. The agricultural sector accounts for a considerable share of the country's GDP. India is home to numerous large-scale farmers, and acres of land are dedicated to agricultural practices. The diverse climate and geography of the country support the cultivation of a wide range of crops, making India a leading producer of various agricultural commodities.

However, with increasing urbanization, many Indians are embracing urbanized lifestyles, leading to a decline in traditional agricultural practices. The essence of agriculture and the joy of cultivating one's own food are being lost in the process. As a result, many individuals are moving away from planting.

Furthermore, many people perceive plant care as a daunting task that requires extensive knowledge and expertise. They often believe that growing plants is a challenging and time-consuming process, which discourages them from even attempting to grow their own plants. Lack of proper knowledge and guidance on plant care and nurturing also contributes to this perception, making it even more difficult for individuals to take up planting and gardening.

Our project aims to address this issue by

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providing a user-friendly and innovative solution that empowers individuals to grow plants with ease. By utilizing AI-driven plant recognition and care, our system offers personalized care recommendations, enabling individuals to overcome common challenges and successfully cultivate their own plants. This solution aims to revive the tradition of home gardening and promote sustainable living, while also providing individuals with the satisfaction of growing their own food.

A Convolutional Neural Network (CNN) model was developed for image classification using a dataset of 2947 grayscaled images. The dataset was divided into three subsets: 70 percent images for training, 20 percent images for testing, and 10 percent images for validation. The CNN model was built using TensorFlow and Keras, leveraging the strengths of these frameworks for deep learning.

The CNN architecture consisted of multiple convolutional and pooling layers, which extracted features from the images. These features were then fed into fully connected (dense) layers, which classified the images into their respective categories. To avoid overfitting, the model employed L2 regularization, which added a penalty term to the loss function.

The model was compiled with the Adam optimizer, which adapted the learning rate during training, and the sparse categorical cross-entropy loss function, which measured the difference between predicted and actual labels. This combination of architecture, regularization, and optimization enabled the model to learn effective features and classify images accurately.I: shows the number of images used in each class of the image dataset used for Classification which will further be divided into training, testing and validation.

TABLE I
DATASET USED FOR CLASSIFICATION

S.No.	class	No. of images
1	cucumber	347
2	curry leaf	330
3	lemon	432
4	mint	302
5	neem	380
6	potato	478
7	pumpkin	278
8	tomato	400

II. LITERATURE REVIEW

Convolutional Neural Networks (CNNs) play a pivotal role in plant identification models due to their ability to extract and learn hierarchical visual features from images. In the context of plant species recognition, CNNs are particularly effective in handling the complex variations in leaf shapes, textures, colors, and venation patterns. These models utilize convolutional layers to capture both low-level features (e.g., edges and textures) and high-level features (e.g., patterns and structures), enabling robust classification even under challenging conditions such as intra-class variability and inter-class similarity.

Advanced CNN architectures, such as multiscale CNNs with attention mechanisms, have been developed to further enhance feature extraction. These models process input images at multiple scales to capture both fine-grained details and broader contextual relationships, improving classification accuracy. For example, the Attention-based Multiscale CNN (AMSCNN) achieved a remarkable accuracy of 95.28% on plant leaf datasets by combining multiscale feature learning with attention mechanisms[**?**]

Additionally, CNNs have been integrated with other advanced techniques like Vision Transformers (ViT) in ensemble models (e.g., Plant-CNN-ViT). These hybrid models leverage the strengths of both CNNs and transformers to capture spatial relationships and fine-grained details, achieving superior performance in plant classification

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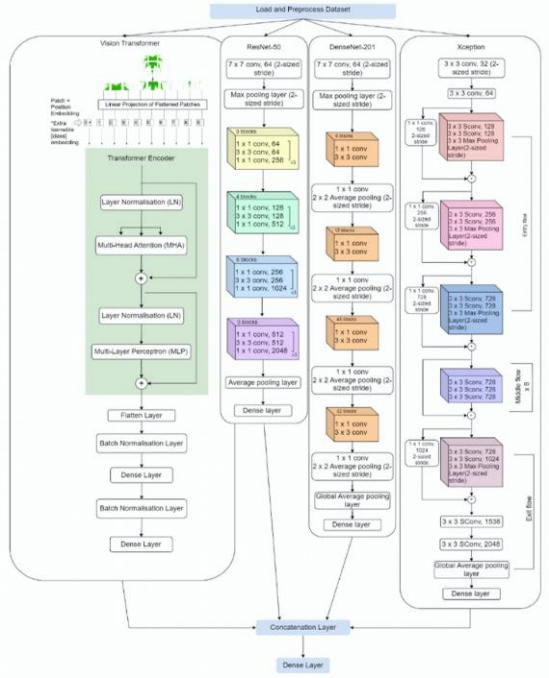

Fig. 1. Architecture of Plant-CNN

tasks.https://www.mdpi.com/2223-7747/12/14/26423 1:The architecture of a CNN model that includes several layers of the CNN model and how each of the layers works.

III. CNN MODEL

This deep learning model uses a convolutional neural network (CNN) architecture and is intended for image classification tasks. There are several levels in the model, each of which

with a distinct purpose and input to the model's overall functionality. The model's core convolutional layers are responsible for obtaining features from the input image. The input image is scanned both horizontally and vertically by the convolutional layers, which apply a series of filters (kernels). These filters are made to capture various elements, including textures, edges, and lines. Edges are identified by filters that pinpoint the image's borders, which are crucial for recognizing objects and shapes. Filters that identify patterns in the image can identify lines and contours, which aid in defining the image's composition and structure. Filters that detect recurring features in an image can identify textures and patterns, which offer crucial hints regarding the image's context and content.

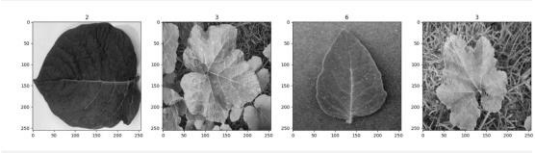

Fig. 2. Preprocessed Input

2 Image Preprocessing: The uploaded image is preprocessed using OpenCV. The image is resized to 256x256 pixels, and then converted to grayscale using the RGB to grayscale function from TensorFlow.

Each convolutional layer's output is run via the Rectified Linear Unit (ReLU), an activation function. By adding non-linearity to the model, ReLU enables it to recognize intricate relationships and patterns in the data. Because of its ease of use and efficiency, ReLU is a popular activation function in deep learning models. A pooling layer, namely MaxPool2D, is then used to downsample the output of each convolutional layer. By doing this, the feature maps' spatial dimensions are decreased, leaving only the most crucial data.

By lowering the model's parameter count, the pooling layers improve efficiency and lessen the likelihood of overfitting. Additionally, they make the model more resilient to minor alterations and distortions in the input image. The output is flattened into a one-dimensional array following several convolutional and pooling layers. This gets the data ready for the fully linked layers, which need an input vector with a specified length.

After that, the output is flattened and sent

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	precision	recall	f1-score	support
0	1.00	1.00	1.00	233
1	0.99	1.00	1.00	268
2	0.98	0.93	0.96	323
3	0.91	0.99	0.95	178
4	0.95	0.87	0.90	231
5	1.00	0.99	1.00	150
6	0.92	0.99	0.96	281
accuracy			0.96	1664
macro avg	0.96	0.97	0.96	1664
weighted avg	0.97	0.96	0.96	1664

Fig. 3. Calculated Metrices

through several thick, completely linked layers. ReLU activation is used in the first dense layer, which has 256 neurons, while softmax activation is used in the last layer, which has 7 neurons. With the help of the features that the convolutional layers have retrieved, the fully connected layers are intended to discover intricate patterns and connections within the data. They use the softmax activation function to generate a probability distribution over the various classes.

3:The evaluation metrics like precision , recall, f1-score are measured and the accuracy is found to be of 96 percent. .

A probability distribution over the various classes is the end result. Based on the attributes taken from the input image, the model is intended to generate a forecast that is both certain and accurate. The sparse categorical cross-entropy loss function and Adam optimizer are included in the model, which makes it appropriate for multi-class classification problems. Because of its ease of use and efficiency, the Adam optimizer is a popular optimization technique in deep learning. Designed to tackle multi-class classification problems using a categorical label as the target variable, the sparse categorical cross-entropy loss function

7gives the confusion matrix

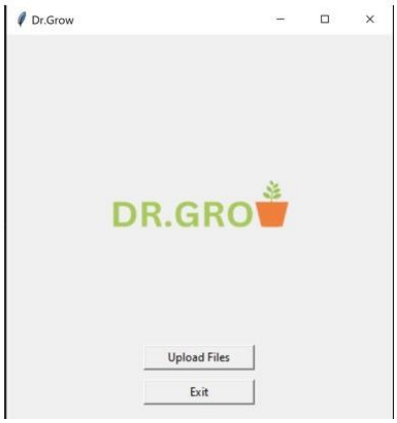

Fig. 4. GUI[a]

Fig. 5. GUI[b]

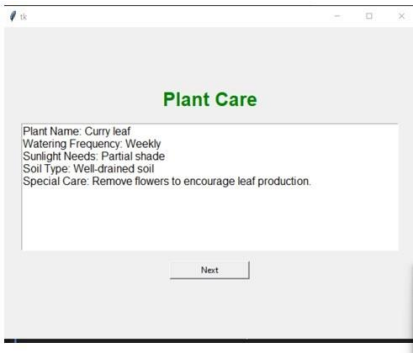

Fig. 6. GUI[c]

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IV. User Interface

The GUI is designed for a plant identification and care system called ”Dr. Grow”. The ”Dr. Grow” logo and the ”Upload Files” and ”Exit” buttons are visible in the GUI’s main window. The user can choose an image file of a plant leaf when they click the ”Upload Files” button, which opens a file window.

The GUI opens a new window titled ”Leaf Classification” after you select an image. The submitted image, the anticipated plant name, and a ”Next” button are displayed in this window

4. A pre-trained machine learning algorithm classifies the uploaded image and predicts the plant name.

Convolutional neural networks (CNNs), the machine learning model utilized in this graphical user interface, were trained using a collection of pictures of various plant leaves. The TensorFlow load model function is used to load the CNN model, while OpenCV is used to pre-process the uploaded image. A probability distribution over the potential plant classes is then produced by the CNN model after the preprocessed image has been run through it.
5.

The class with the highest likelihood is used to determine the anticipated plant name. The argmax function, which yields the index of the probability distribution’s maximum value, is used for this. Next, from a list of class names, the matching plant name is obtained.

A pane providing plant care details, such as soil type, sunlight requirements, watering frequency, and special care needs, is also displayed by the GUI.

6The anticipated plant name is used to retrieve this data from a database.

V. Conclusion

This study describes the creation of a novel AI-powered plant identification system that makes use of machine learning and computer vision methods. By giving customers individualized care instructions, the system hopes to enable users to properly care for their plants. The technology could transform how people engage with plants by developing a model that correctly detects different vegetable species, making gardening more approachable, effective, and pleasurable.

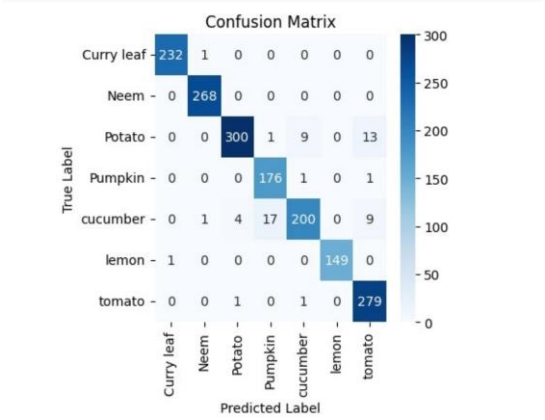

Fig. 7. Confusion Matrix

With an emphasis on improving the accuracy of the model, investigating deep learning methods, and creating an intuitive user interface, the suggested system has advanced significantly. Future developments will focus on strengthening the system’s resilience, looking into the usage of deep learning methods, and developing an easy-to-use user interface.

This project’s AI-based plant recognition and care system has the potential to completely change how people take care of their plants. Through the use of computer vision and machine learning, the system offers tailored care advice, enabling people to effectively grow their own plants and overcome common obstacles.

A major advancement in the field of plant care is the system’s capacity to precisely identify plant species and offer customized advice for ideal growth. The system can discover efficient features and correctly categorize pho-

tos by using a Convolutional Neural Network (CNN) model that was trained on a dataset of 2428 grayscaled images. The model avoids overfitting and adjusts to the learning rate during training thanks to the use of L2 regularization and the Adam optimizer.

This system has important ramifications for environmentally resilient living and sustainable living that go beyond the field of plant care. The program fosters a sense of accountability and stewardship for the natural environment by giving people the skills and information they need to properly care for plants. Additionally, the method may help create a more ecologically conscious future by reviving the home gardening heritage and encouraging sustainable living.

This project's success serves as evidence of the value of multidisciplinary research and teamwork. The researchers have developed a system that is both technically complex and practically applicable by fusing their knowledge in computer vision, machine learning, and plant care. From inexperienced gardeners to seasoned agricultural professionals, a broad spectrum of users can benefit from the system's intuitive interface and tailored care advice.

To sum up, this project's AI-based plant identification and care system has the potential to revolutionize how people take care of their plants. The system helps create a more ecologically conscious future by encouraging sustainable living and offering tailored care recommendations. The system will probably have a significant influence on how we engage with plants and the natural world as it develops and gets better.

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FARM PROTECTOR

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***Abstract*—India is a rustic country renowned for its agricultural area, which plays a pivotal role in the country's economic system. Farmers and cultivators are the spine of this industry, providing food for the country and providing employment to more than half of the population. They cultivate a ramification of plants, including staples such as rice, wheat, and pulses, in addition to coins such as cashews, cotton, and more. The majority of cultivation takes place in rural areas, where farmers face a large assignment, attacks with the aid of wild animals. Species such as elephants, monkeys, wild boars, and others frequently project onto farmlands, causing widespread damage to crops. This destruction results in financial losses for farmers, affecting their livelihoods and affecting the nation's food safety. This paper identifies the animals that threaten agricultural land and indicates opportunity crops which are much less prone to such animal invasions, assisting farmers mitigate harm and defend their agricultural output with a non-harmful repellent system.**

***Index Terms*—YOLOv5,Animal Repellent System, Prevention Recomendation**

I. INTRODUCTION

INDIA'Sagriculture sector plays a crucial role in the economy, providing livelihoods for millions and supporting food security. However, wild animals often cause significant damage to crops, resulting in financial losses for farmers and threatening food production. The types of damage vary depending on the region, species, and crops, with common culprits including elephants, wild boars, monkeys, and deer. To address this issue, farmers, government agencies, wildlife conservation groups, and local communities work together on solutions. These include building physical barriers such as fences and electric wires, creating community-based strategies like planting less attractive crops, and using noise devices to scare animals away. The government also offers financial assistance to farmers affected by wildlife-related crop damage, and conservation efforts focus on creating wildlife corridors and raising awareness about balancing wildlife preservation with agricultural needs. Despite these efforts, the conflict remains an ongoing challenge that requires continuous collaboration and adaptation to ensure both agricultural productivity and biodiversity are protected.

The objective of this research is to assist farmers in taking swift and effective action to address the damage caused by wild animals, which frequently leads to the destruction of crops. This involves three main components: (a) the detection of animals that enter the fields and the regulation of their frequency of attack or entry, (b) providing farmers with suggestions for crops that are less likely to be attacked by the animals that cause regular destruction, or offering methods to protect their crops from animal attacks, and (c) developing a sound system to work alongside the detection and suggestion mechanisms, ensuring that the animals are deterred and leave the fields after hearing the sounds. Through these combined efforts, the research aims to offer practical solutions for farmers to prevent and minimize the damage caused by wildlife, contributing to more effective and sustainable agricultural practices.There are a few challenges that are faced while doing this system, which include: a) animal identification and behavior of each species being different, and they can adapt themselves based on the detection strategies. b) Some animals are active during the nighttime, making it much harder to detect them. c) Economic and technology limitations, which include the limited coverage of cameras as well as the cost to be incurred by the farmers to keep the field under observation. Mostly, the accuracy of detection of animals plays a vital role in the animal detection model under an embedded device with low computational power.

The project aims to address the issue of animals causing destruction in agricultural fields in India by detecting these animals and recommending suitable crops to minimize damage. The dataset used in the project contains images of 10 animals that are commonly seen attacking fields, and these images have been labeled using RoboFlow 1:helps identify the animals and their features. Labeling the data provides the model with the correct classifications, allowing the machine learning model to learn the patterns and make accurate predictions for object detection. For this project, YOLOv5 is used, a fast and efficient object detection model known for its accuracy and real-time performance. YOLOv5 is ideal for identifying and localizing objects in images or videos quickly, as it processes the entire image in a single pass. This makes it suitable for applications requiring real-time detection of multiple objects, such as identifying animals in agricultural fields. The objective is to detect the presence of animals that cause destruction and subsequently recommend appropriate crops for the affected fields.

The labeled dataset helps train the YOLOv5 model to recognize various species, with each image labeled to include the species and the location of the animal in the image through bounding boxes. The next step involves fine-tuning the YOLOv5 model with the dataset, ensuring the model accurately detects the animals. Different hyperparameters, such as learning rate and batch size, can be experimented with to optimize the model's performance, and data augmentation

techniques like flipping, rotation, and cropping can help improve its robustness. Once trained, the model can be deployed for real-time animal detection in agricultural fields, providing farmers with a tool to monitor and respond to animal-related damage promptly. Additionally, an algorithm can be developed to recommend crops based on the detected animals, soil conditions, and climate factors, suggesting the most suitable crops for minimizing the risk of damage from these animals. The system can also consider environmental conditions, animal patterns, and historical data to recommend crops that are more resistant to specific animals or suggest deterrents. The accuracy of the model should be evaluated under various conditions to ensure its effectiveness, and feedback from field tests will help refine the crop recommendation system

A. LITERATURE REVIEW

Paper 1: smart CROP safety machine the use of DEEP getting to know The machine is an AI-based Scarecrow that makes use of YOLOv3 for real-time animal detection in fields. It triggers signals (sound, e mail, phone) to inform farmers when animals are detected, supplying a greater efficient and automatic answer than conventional strategies. we're focusing on the alert device with which we are seeking to create a legitimate that could dispose of wild animals who input the fields.

Paper 2: An accurate and speedy Animal Species De- tection machine for Embedded gadgets The device uses an optimized YOLOv2 model for real-time animal detection to prevent wildlife-vehicle and natural world-human conflicts. It improves accuracy and pace through function merging, layer removal, and deformable convolutional layers (DCLs). De- signed for embedded gadgets, it provides an efficient answer for natural world monitoring and twist of fate prevention.

Paper 3: Airep: Ai And Iot primarily based Animal recognition And Repelling device For smart Farming They are seeking to broaden a device to shield plants from wildlife the usage of AI-based totally animal detection and ultrasound repelling. The device makes use of Deep Convolutional Neural Networks (DCNN) for animal popularity and activates a particular ultrasound primarily based on the detected animal species to repel it. This method is extra efficient and environmentally friendly as compared to traditional, luxurious, or dangerous natural world deterrent strategies.

Paper 4: Detection Of Animals In Agricultural Land and the use of CNN They are developing an AI system to defend plants from animals. the use of cameras and deep gaining knowledge of (CNN), the gadget detects animals getting into the farm. PIR sensors help with movement detection, and as soon as an animal is spotted, sound deterrents are trigger sounds that repel the animal with out harming it.

Paper 5: actual-time Animal Detection and Prevention machine for Crop Fields : they're developing a gadget to stumble on wild animals in crop fields and set off scare mechanisms. The device makes use of CNN models (VGGsixteen) for animal classification, Raspberry Pi for image processing, and a thermal sensor on Arduino to detect animals. once detected, scare methods like mild flashes, ultrasound, and bee sounds are prompted, and the farmer is alerted thru a cell app.

B. OBJECT DETECTION

Object detection is a computer vision undertaking that entails figuring out and locating items inside an image or video. The intention is to now not only classify gadgets(e.g., recognizing that an object is a cat or a vehicle) however also to determine their specific role inside the body, state-of-the- art via drawing bounding bins around them. Item detection is a venture that involves figuring out and finding objects inside a picture or video . This manner is usually accom- plished the use of device cutting-edge algorithms, especially Convolutional Neural Networks (CNNs), which are educated to recognize styles and capabilities in snap shots. The first step in object detection is picture preprocessing, where the enter photo is prepared for analysis by using resizing, normalizing, or converting it to grayscale. After that, function extraction takes place, where in the CNN analyzes the photograph to perceive key features like edges, shapes, and textures. Once these features are extracted, the version classifies the poten- tial items inside the picture into predefined classes, which include a automobile, individual, or dog. Concurrently, the model performs localization, which determines the suitable location today's object by drawing bounding boxes around them. These bounding packing containers are described by means of coordinates that imply the object's position in the image. Subsequently, put up-processing techniques like Nonmaximum Suppression (NMS) are carried out to state-of- the art redundant bounding bins for the identical item, ensuring accuracy.

Common place algorithms used for item detection consist of YOLO , which offers rapid actual-time detection, faster R-CNN, which is understood for its accuracy but is computationally heavier, and SSD (unmarried Shot MultiBox Detector), which strikes a balance between pace and accuracy. Item detection has numerous packages, consisting of in independent cars, where in it is used to stumble on pedestrians and traffic symptoms, in security surveillance for identifying intruders, in medical imaging for detecting tumors, and in retail for product popularity on cabinets. In essence, item detection combines each classification and localization responsibilities to perceive and precisely locate gadgets in images, the usage of superior algorithms for green and actual-time evaluation.YOLO (You Only look once) plays item detection with the aid of dividing an image right into a grid and predicting bounding boxes, object scores, and class chances for every grid cell in an unmarried skip.

The network outputs those predictions for all capacity gadgets, and then Nonmost Suppression (NMS) is carried out to remove redundant packing containers and maintain the maximum accurate ones. This approach permits YOLO to stumble on more than one gadgets in real-time, making it rapid and green, as it combines both categoryand localization into a unmarried, unified model. YOLOv5 performs item detection through first preprocessing the enter image, then extracting capabilities the usage of a spine community like CSPDarknet53. It aggregates multi-scale capabilities thru a neck community (PANet) to decorate detection trendy gadgets at unique sizes. The detection head predicts bounding packing

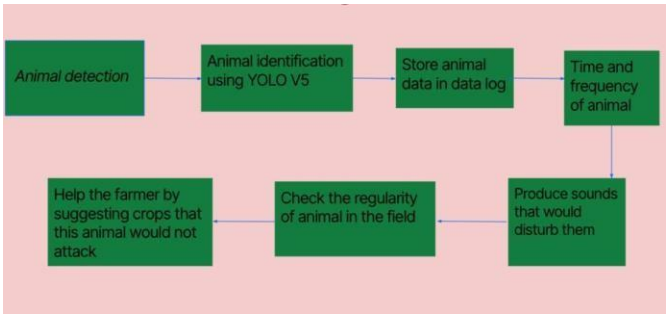

Fig. 1. . data flow diagram regarding the steps involved in the process

containers, objectness scores, and sophistication probabilities for every grid cellular in the picture, with the assist trendy anchor packing containers.

After making predictions, YOLOv5 applies Non-maximum Suppression (NMS) to state-of-the-art redundant bounding packing containers, leaving most effective the most confident predictions. YOLOv5 is designed for velocity and accuracy, imparting advanced overall performance and versatility, making it perfect for actual-time programs.YOLOv5 gives numerous blessings for item detection, making it a famous desire for real-time packages. it is designed for high-velocity overall performance, allowing it to procedure images in actual-time, that is critical for tasks like self reliant motors, surveillance, and robotics. YOLOv5 achieves a stability latest velocity and performance, running nicely on less powerful hardware, inclusive of part gadgets or GPUs with lower computing power.

The version additionally contains improvements in function extraction and multi-scale characteristic aggregation, leading to better accuracy, particularly for detecting small or com- plex objects. It's far enormously modular and cleanto adapt for exclusive datasets and particular obligations, with simple configuration documents that make it user-pleasant for each novices and skilled practitioners. YOLOv5 competes with fashions like quicker R-CNN and Retina Net, offering a robust overal performance balance among accuracy and velocity. With preskilled fashions available for switch present day, it enables lessen schooling time on custom datasets. YOLOv5 is good for actual-time applications today's its speedy processing pace and capability to locate more than one items concurrently. moreover, it has a robust community and lively support, making sure continuous development and optimization for a wide range trendy use cases.

II. OUR DATASETS

Our dataset contains variety of 10 animals such as Elephant ,Wild Boar, Indian peafowl,Indian crested porcupine,Bonnet Macaque (Macaca radiata),Common Langur (Presbytis entellus),Malabar giant squirrel,Barking deer,Palm civet ,sambar . Animals like elephants, wild boars, and monkeys often cause significant damage to agricultural fields. These animals, driven by the need for food, often clash with farmers, causing both economic losses and human-wildlife conflict. Efforts to manage this include fencing, repellents, and habitat restoration. Each animals contains 200 images and they have a resolution of 640x640. The images are then sorted into training, validation and test sets in each containing 70 ,20 and 10 images.

III. METHODOLOGY

The "Animal Detection in a Field and Crop Suggestions" mini-project uses YOLOv5 for real-time detection of animals that might threaten crops. In order to label the data sets we use roboflow application.First, a dataset of animals (like elephants, wild boars, and monkeys) and crops is suggested to farmers that these animals won't attack or crops that could protect others due to their presence . YOLOv5 is then trained on this data to detect animals in field videos. Once animals are detected, the system cross-references a database of crop types and their susceptibility to specific animals to suggest crops less likely to be attacked. After which sounds are produced to scare these animals away from the fields .A user interface is developed to display realtime animal detection and crop suggestions, helping farmers make informed decisions on what to plant. The model is continuously evaluated for accuracy and refined with more data to improve performance over time.

A. YOLO v5 DETECTION ALGORITHM

The YOLO (You handiest look as soon as) algorithm is a quite efficient item detection approach that plays item category and localization in a unmarried, unified procedure. unlike traditional strategies that use separate steps for those obligations, YOLO makes use of a unmarried convolutional neural community (CNN) to are expecting bounding bins and class probabilities simultaneously. The photograph is divided into a grid, and each grid cellular is responsible for detecting items whose center lies within it. For every grid cell, YOLO predicts more than one bounding containers with coordinates, confidence rankings, and sophistication chances.

The final output includes a listing of bounding bins with related elegance labels and confidence rankings, detecting gadgets in the image. YOLO is understood for its speed and real-time processing abilties, making it best for video and live programs. Its quit-to-stop schooling method and the capacity to manner the whole image right away provide a worldwide context, which allows reduce false positives.YOLOv5 is a fantastically green and superior model of the YOLO (You handiest appearance once) item detection algorithm, designed to provide real-time, excessive-accuracy object detection. in contrast to previous variations, YOLOv5 became evolved independently by way of the community and is built at the PyTorch framework, making it greater available and less complicated to install as compared to its predecessors, which used the Darknet framework

. YOLOv5 improves upon in advance versions via introducing numerous key upgrades, inclusive of better accuracy, speed, and scalability. It uses a greater subtle architecture, which includes a spine network (which include CSPDarknet53), a neck (PANet), and a head (YOLOv5 detection head), optimizing both feature extraction and the ability to handle items at multiple scales. YOLOv5 contains strategies like car gaining knowledge of rate adjustment, mosaic information

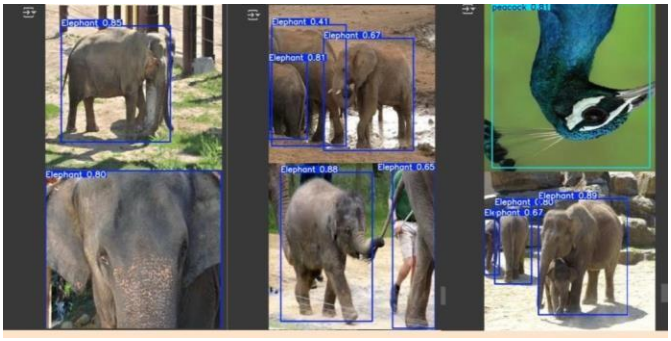

Fig. 2. :
animal detection using YOLO v5 of elephant and peacock with accuracy as elephant 41 to 88 perrcent and peacock as 81 percent

augmentation, and progressed anchor field strategies, all of which beautify its capability to come across smaller items with higher precision and fewer false positives. The model additionally offers numerous variations (e.g., YOLOv5s, YOLOv5m, YOLOv5l, and YOLOv5x) to house distinctive use cases based totally on alternate-offs among accuracy and velocity, with lighter versions optimized for speed and larger ones specializing in higher accuracy. moreover, YOLOv5 is optimized for ease of education and inference, making it user-pleasant for each research and production environments. Its integration with current gear including TensorRT for hardware acceleration and ONNX for go-platform deployment has made YOLOv5 one of the most popular and extensively used object detection algorithms in both instructional and enterprise programs.

B. REPELENT SYSTEM

A repellant system using speakers to remove animals from fields works by emitting sounds that are unpleasant or alarming to animals, deterring them from entering or staying in agricultural areas. The system typically uses ultrasonic frequencies, predator sounds, or distress calls that are specifically tailored to the hearing ranges and natural responses of the target animals, such as deer, birds, or rodents. These sounds create discomfort or trigger an instinctual flight response, encouraging the animals to leave the area.The system is often equipped with motion sensors or cameras to detect animal presence, activating the speakers when animals are detected. The speakers are strategically placed around the field and are weather-resistant, offering broad coverage. Power sources include solar panels, batteries, or an electrical grid, with solar power being a popular option for remote areas. The system is non-lethal, eco-friendly, and cost-effective, as it avoids the use of harmful chemicals or physical barriers. However, its effectiveness can be limited by animals adapting to the sounds over time, species-specific reactions, and potential noise pollution affecting nearby residents.

IV. RELATED WORK

A. ANIMAL SPECIES DETECTION

Animal species detection entails identifying and classi- fying species the usage of technologies like photograph and video evaluation, audio recognition, movement sensors, and DNAbarcoding. Those techniques help reveal flora and fauna,track animal populations, and support conservation efforts through analysing visible, auditory, and genetic statistics.Animal detection in fields in rural regions refers to theuse of era to perceive and monitor animals in agriculturalor herbal environments. this can contain equipment like movement-sensing cameras, drones, or infrared sensors tostumble onthe presence of animals in actual-time. Those technologies assist farmers, wildlife conservationists, and researchers screen natural world pastime, shield plants from herbivores, and track livestock. Gadget getting to know algorithms can also examine pictures or motion pictures captured by way of cameras to pick out particular species,at the same time as audio sensors can come across animal sounds. This detection aids in managing wildlife populations,stopping crop damage, and ensuring the health and protection of animals in rural regions. We have created datasets of 10 animals containing 200 images in every primarily based on thefrequency of attack seen by way of these in Indian fields.

B. ANIMAL SOUND REPELLENT SYSTEM

Animal detection systems come in various types, each suited to different applications. Infrared camera-based systems detect heat signatures, while radar sensors track movement through radio waves. Ultrasonic and motion detection systems sense changes in the environment to identify animals. Camera traps capture images triggered by animal movement, and LIDAR uses laser light to create 3D maps for identifying animals. Additionally, AI and machine learning-based systems analyze images to automatically identify and track animals. These technologies are used for wildlife monitoring, road safety, and farm management.

Current research on animal detection systems can be divided into two directions: using traditional machine learning (ML) algorithms, which rely on feature extraction descriptors to detect animals , and using deep learning (DL) algorithms, which rely on Convolutional Neural Networks (CNNs). After the detection of animals sounds that disturb them are produced using speakers in order to scare the animals away from the fields.YOLOv5 is a fast and accurate deep learning model used for real-time animal detection in images or videos. It can identify and track animals in various settings, such as wildlife monitoring, road safety, and farm management, by using convolutional neural networks to classify and locate animals.

Its speed and precision make it ideal for real-time applications.In rural areas, various animals can damage crops and fields. Elephants trample over crops, while wild boars root through fields, destroying vegetables. Peafowls peck at grains, and porcupines uproot plants. Monkeys, like the Bonnet Macaque and Common Langur, raid orchards, and Malabar giant squirrels damage tree crops. Barking deer graze on young

plants, and palm civets steal fruits. Sambar deer also graze on crops, leading to conflicts between wildlife and farmers.

V. PROPOSED ANIMAL DETECTION MODE

The proposed animal species detection model leverages YOLOv5, a state-of-the-art deep learning architecture known for its speed and accuracy in real-time object detection. YOLOv5 is specifically chosen for its ability to efficiently identify and localize various animal species in images and video streams, providing precise bounding boxes and class labels for each detected animal. By utilizing a robust dataset of labeled animal species, the model can be trained to distinguish between different species with high accuracy. The implementation of YOLOv5 allows for rapid inference, making it an ideal solution for wildlife monitoring, conservation efforts, and automated animal recognition in diverse environments. This approach is not only scalable but also adaptable to different animal datasets, ensuring its applicability in various domains, from ecological studies to wildlife tracking.The proposed system integrates YOLOv5 for animal species detection with a sound repellent mechanism, creating an automated solution for managing animals in the field. Once YOLOv5 detects a specific species, the system triggers a sound repellent to deter the animal. This approach enables non-lethal, real-time animal control, especially in agricultural or conservation areas, by using species-specific sounds to drive animals away. The integration of the detection model with the sound system ensures effective field management with minimal human intervention

VI. EVALUATION METRICS

Evaluation metrics are tools used to assess the performance of a model or system. In machine learning, these metrics help quantify how well a model is making predictions or classifications. For example, in classification tasks, common metrics include accuracy, precision, recall, and F1- score, while for regression tasks, metrics like Mean Squared Error (MSE) or R-squared are often used. The choice of metric depends on the specific problem and what aspects of performance are most important to evaluate. In object detection models, evaluation metrics like Train/Box Loss and Val/Box Loss measure how accurately the model predicts bounding boxes during training and validation. Train/Obj Loss and Val/Obj Loss assess how well the model detects whether an object exists in the bounding boxes. Class Loss evaluates the accuracy of object classification, while Precision and Recall measure the model's ability to correctly identify objects and minimize false positives or negatives. Lastly, mAP (Mean Average Precision) averages precision across classes, providing an overall performance measure. These metrics together evaluate the model's object detection, localization, and classification effectiveness. The following diagrams depict these graphically in the program and how the datasets are being depicted.VOLUME ,

Class	Images	Instances	P	R	mAP50	mAP50-95: 100% 10/10 [00:06<00:00, 1.48it/s]
all	314	387	0.496	0.538	0.511	0.258
Elephant	314	84	0.492	0.679	0.577	0.293
Peacock	314	49	0.386	0.714	0.466	0.178
Wild boar	314	53	0.447	0.275	0.336	0.171
barking deer	314	51	0.553	0.438	0.487	0.267
bonnet maccaque	314	50	0.311	0.14	0.206	0.111
indian porqupine	314	53	0.685	0.906	0.904	0.492
malabar wild squirrel	314	47	0.595	0.617	0.597	0.291

Fig. 3.
instances,precision(P),recall(R),mAP50 of the animals calculated while running the program, based on the datasets taken

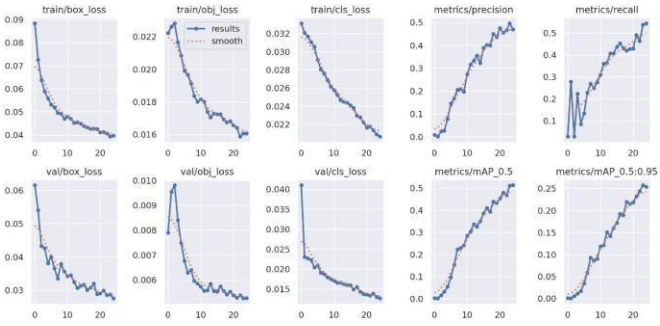

Fig. 4. Evaluation metrics containing box loss , precision ,recall,mAP graphically

CONCLUSION

In conclusion, this project has effectively addressed the challenge of protecting crops from animal infestations through

a multi-faceted, innovative approach. By utilizing animal detection systems, the project accurately identifies animals that are prone to attacking crops, allowing for timely intervention. The implementation of sound-based repellents has proven to be an effective and humane way of deterring these animals without the need for harmful chemicals or physical barriers, making it an environmentally friendly solution.Moreover, the system goes beyond just scaring the animals away; it provides farmers with valuable insights by recommending alternative crops that are less likely to attract these animals. This proactive approach ensures that farmers can optimize their crop choices to avoid recurring damage, leading to more sustainable agri- cultural practices.The highest detection is seen for elephants and the lowest for porcupine .

The future scope of this project presents numerous opportunities to enhance agricultural practices and sustainability. It focuses on sustainable, non-toxic solutions that protect crops without harming animals, ensuring a better quality of life for both farmers and wildlife. By reducing crop losses and improving security, the system enhances food security and stabilizes farmers' incomes. AI models hold great potential in predicting animal behavior and improving detection accuracy, while data collection provides valuable insights into wildlife dynamics. Additionally, the project can benefit from government support through initiatives like *Digital India* and *PMFBY*, which offer financial backing and policy support for nationwide implementation.With advancements in drone and satellite technology, large farms can benefit from remote monitoring, tracking animal movements over vast areas in real time.

Public awareness campaigns and training programs for farmers will help increase adoption, with community involvement in data-sharing enhancing the system's effectiveness. In conclusion, this project has the potential to significantly improve agricultural productivity and sustainability in India by reducing wildlife-induced crop losses and enhancing food security. The use of YOLO v5 facilitates efficient data analysis, but challenges like high costs, infrastructure limitations, and the need for skilled labor need to be addressed. Successful implementation will require careful planning, collaboration, and support from various stakeholders.Ultimately, this initiative can transform farming practices, protect wildlife, and contribute to the long-term success of Indian agriculture, creating a more sustainable and secure future for both farmers and ecosystems.

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AI-Powered Crop Disease Detection using Convolutional Neural Networks (CNN): A Focus on Tomato and Cauliflower with Tailored Recommendations

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***Abstract*—In modern agriculture, early detection of plant diseases is crucial for ensuring sustainable crop production and minimizing yield loss. Our project, 'AI-Powered Crop Disease Prediction Using Convolutional Neural Networks (CNNs)' — focuses on tomato and cauliflower, with tailored recommendations. It presents an intelligent solution for automated disease detection in tomato and cauliflower crops. Using CNNs, the system processes leaf images to classify plant health conditions and predict diseases with high accuracy. The model leverages CNNs to extract features and recognize patterns indicative of specific dis- eases. The dataset includes multiple disease categories alongside healthy samples, ensuring comprehensive detection capabilities. Furthermore, the application provides tailored recommendations for disease management, offering farmers actionable insights to mitigate crop damage. By integrating advanced AI with precision agriculture, this solution enhances decision-making, optimizes resource utilization, and contributes to sustainable farming practices, bridging the gap between technology and agriculture in the era of smart farming.**

***Index Terms*—Sustainable Farming, Convolutional Neu- ral Networks(CNNs), Treatment Recommendations, Crop Dis- ease Prediction,Machine Learning In Agriculture,User Interface,Artificial Intelligence,Integrated Development Farming .**

I. Introduction

This study focuses on AI-driven crop disease prediction using Convolutional Neural Networks (CNNs), with a specific emphasis on tomato and cauliflower plants. Early and accurate detection of plant diseases is essential for enhancing agricultural productivity and sustainability. By leveraging deep learning techniques, this research aims to assist farmers in identifying plant diseases at an early stage and providing tailored recommendations for effective management.

A strong foundation in machine learning, deep learning, and image processing is required to comprehend the methodologies employed in this study. The experiment utilizes CNNs for classification, integrating dataset preprocessing, feature extraction, and performance evaluation. While alternative techniques such as Support Vector Machines (SVM) and Decision Trees exist, CNNs were chosen due to their supe- rior ability to process image-based data and achieve higher classification accuracy.

The experiment was conducted by training a CNN model on a dataset comprising healthy and diseased leaf images of tomato and cauliflower. The dataset underwent preprocessing, including resizing, normalization, and augmentation, to improve model performance. The technological framework included Python, TensorFlow, and OpenCV, with GPUs utilized for accelerated training. Performance was evaluated using key metrics such as accuracy, precision, recall, and confusion matrices. Additionally, hyperparameter tuning was performed to optimize learning rates, batch sizes, and convolutional layers, ensuring efficient model learning and prediction accuracy.

Technical writing is a critical skill for effectively communicating research findings and methodologies. Mastering structured documentation, including formatting, equation editing, and graphical representation, is essential for producing high-quality reports. In industrial and research settings, professionals are often required to draft technical reports, proposals, and user manuals. This report adheres to industry standards for technical documentation, ensuring clarity and precision in presenting research outcomes.

Technical writing plays a vital role in effectively communicating research findings and methodologies. Developing proficiency in structured documentation, including formatting, equation editing, and graphical representation, is essential for producing high-quality reports. In an industrial setting, professionals are expected to draft technical reports, proposals, and user manuals, making strong writing skills a critical asset for career advancement. This report aims to present the research findings in a structured and professional manner, adhering to industry standards for technical documentation.

II. LITERATURE REVIEW

A proliferation of literature is available in plant leaf disease detection using deep learning techniques. We will highlight some of the key contributions.

A methodology for detecting plant diseases using Convolutional Neural Networks (CNNs) was proposed by M. Shobana et al. [1]. Their approach leverages CNN architectures to classify plant diseases efficiently, demonstrating improved accuracy compared to traditional image processing methods. The study highlights the importance of deep learning in automating disease detection.

Pranali K. Kosamkar et al. [2] developed a CNN-based model for leaf disease detection and recommended appropriate pesticides. The model was trained on a dataset of diseased leaves and achieved high classification accuracy. Their research emphasizes the practical application of AI in precision agriculture.

A comprehensive bibliometric analysis of deep learning applications in leaf disease detection from 2014 to 2024 was conducted by Jyotismita Chaki et al. [3]. The study visualizes research trends, highlighting the evolution of CNN architectures and their impact on plant disease diagnosis. This research provides valuable insights into advancements in the field.

Abdelmalik Ouamane et al. [4] introduced a novel CNN-based approach that integrates Tensor Subspace Learning and HOWSVD-MDA for enhanced plant disease detection. Their method achieves superior performance by optimizing feature extraction and classification processes, making it a promising tool for large-scale agricultural monitoring.

Diana Susan Joseph et al. [5] developed a real-time plant disease dataset and implemented deep learning models for detection. Their research focuses on improving dataset quality and annotation, leading to more reliable disease classification. This study contributes to the standardization of plant disease datasets for future AI applications.

Shanta Patil et al. [6] explored plant leaf disease detection and classification using both image processing and deep learning techniques. They employed CNN architectures and traditional feature extraction methods, demonstrating that hybrid approaches can enhance disease identification accuracy. Their study bridges the gap between conventional and modern techniques.

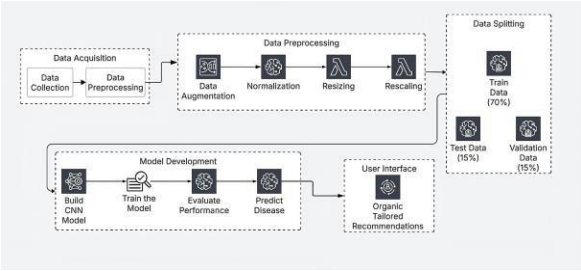
Vaishali Bitla et al. [7] proposed a CNN-based model for leaf disease detection and remedy suggestion. Their model not only classifies plant diseases but also provides recommendations for treatment, making it a practical tool for farmers and agriculturalists. This research emphasizes the integration of AI-driven disease management solutions.

These studies collectively illustrate the effectiveness of CNN-based models in plant disease detection. The integration of AI techniques with agricultural practices has led to significant improvements in disease identification, classification, and management, contributing to the advancement of smart farming solutions.

III. METHODOLOGY

Crop diseases pose a significant threat to global food security, often leading to reduced yield and economic losses. Traditional disease identification methods require expert knowledge and are time-consuming. This paper presents an AI-based crop disease detection system utilizing Convolutional Neural Networks (CNN) for automated classification. The system architecture follows a structured pipeline, including image preprocessing, deep learning-based classification, and disease-specific organic treatment recommendations. This approach not only ensures real-time disease detection but also minimizes the dependency on human expertise, making it accessible for farmers in remote areas.

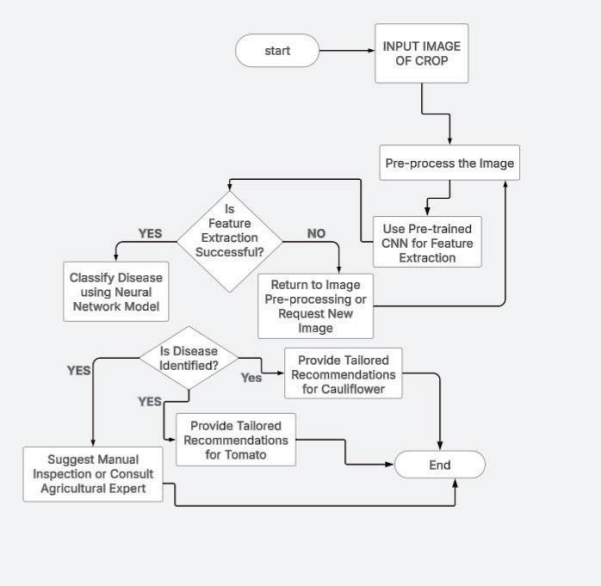
1) SYSTEM ARCHITECTURE: The system architecture is designed for crop disease detection and recommendation. It follows a structured pipeline where an image of a crop is processed using deep learning techniques, specifically a pre-trained Convolutional Neural Network (CNN) for feature extraction. If the features are successfully extracted, a neural network-based disease classification model is used to identify crop diseases. If a disease is detected, the system provides tailored recommendations based on the crop type. In cases where the disease cannot be classified, it suggests manual inspection or expert consultation.



The AI-Powered Crop Disease Prediction System streamlines plant disease detection and provides organic recommendations for farmers. It begins with data acquisition, collecting images of healthy and diseased tomato and cauliflower plants from public datasets like Kaggle. These images undergo preprocessing—augmentation (rotation, flipping, brightness adjustment), normalization, resizing, and rescaling—to improve dataset diversity and quality. The dataset is then split into training, testing, and validation sets to ensure effective model generalization.

A Convolutional Neural Network (CNN) forms the system's core, extracting key features through multiple convolutional layers. The model is trained on labeled images, refining accuracy and efficiency. Performance is assessed using metrics like accuracy and loss to ensure reliable disease classification. Once trained, the model predicts plant diseases

from uploaded images, classifying them into predefined categories. A user-friendly interface allows farmers to upload plant images for instant diagnosis. Based on predictions, the system provides organic, tailored recommendations for effective disease management and improved crop health. This AI-driven solution enhances efficiency, accuracy, and accessibility, promoting sustainable farming practices.



The Data Flow Diagram (DFD) of the AI-Powered Crop Disease Prediction System outlines the structured data flow for accurate disease detection and treatment recommenda- tions. The process starts with farmers uploading images of tomato or cauliflower plants. The system verifies and pre- processes the image, enhancing quality through techniques like noise removal, resizing, and augmentation. A pre-trained CNN then extracts key features for classification.

If the plant is healthy, tailored recommendations are provided. If diseased, the system identifies the plant type and suggests organic treatments. For severe or unknown infections, expert consultation is recommended. The final output delivers a detailed diagnosis and recommended actions while storing data for further analysis. The DFD ensures clarity with standard symbols, improving efficiency, accuracy, and accessibility in AI-driven farming support.

2) DATA COLLECTION: The data collection process plays a crucial role in the development of an accurate and efficient crop disease detection system. The dataset used for this project is sourced from Kaggle, a widely recognized plat- form for open-access machine learning datasets. The dataset consists of high-resolution images of tomato and cauliflower leaves, each categorized based on whether the leaf is healthy or affected by a specific disease. The goal of this dataset is to enable a deep learning model, specifically a Convolutional Neural Network (CNN), to distinguish between different plant diseases with high precision.

The dataset comprises two major plant species: tomatoes and cauliflowers, with multiple disease classes for each. The tomato dataset consists of ten classes, including one healthy class and nine disease classes. The cauliflower dataset, on the other hand, consists of four classes, including one healthy class and three disease classes. Each image is labeled accord- ingly to facilitate supervised learning, allowing the model to learn distinct patterns associated with each disease type.

3) PREPROCESSING: Data preprocessing is a fundamental step in ensuring that the collected images are in a suitable format for training the Convolutional Neural Network (CNN) model. The raw dataset consists of images with varying dimensions, resolutions, and lighting conditions, which can negatively impact model performance if not processed correctly. To address this, several preprocessing techniques are applied, including image resizing, normalization, data augmentation, and dataset splitting.

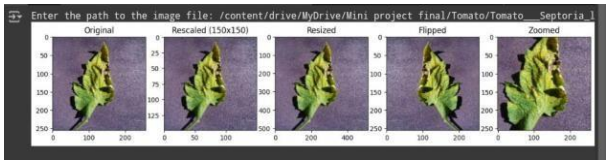
First, all images are resized to a uniform dimension of 150×150 pixels, ensuring consistency in input size and preventing shape mismatch errors during training. This resizing step balances computational efficiency and feature retention, making it easier for the CNN to extract meaningful patterns from the images. After resizing, the images undergo normalization, a crucial process that scales pixel values from their original range of 0 to 255 to a normalized range of [0,1]. This transformation helps stabilize the training process, speeds up convergence, and ensures that the model learns efficiently without being affected by large variations in pixel intensity. The normalization process follows the formula , where X represents the original pixel value.

To enhance the model's generalization ability and pre- vent overfitting, data augmentation techniques are applied to artificially expand the dataset by introducing variations in

image properties. Several augmentation strategies are used, including random rotations up to 30 degrees, which help the model recognize plant diseases from different orientations. Horizontal and vertical flipping are applied to account for variations in leaf positioning, while zooming (up to 10%) introduces scale changes, enabling the model to detect diseases at different zoom levels. Additionally, brightness adjustments simulate varying lighting conditions, making the model robust to images captured under different illumination settings. Finally, shearing transformations slightly modify image angles, introducing geometric distortions that further improve the model's ability to recognize disease patterns from different perspectives. These augmentation techniques collectively ensure that the model does not become overly reliant on specific image characteristics and is adaptable to real-world variations in plant leaves.

After preprocessing, the dataset is split into three subsets to facilitate effective training and evaluation. The training set (70%) is used to train the model by learning disease patterns from the augmented images. The validation set (15%) is used for hyperparameter tuning and to monitor performance during training, helping prevent overfitting. The test set (15%) remains unaltered and is used for final model evaluation on unseen data, providing a reliable measure of its real-world accuracy.

In conclusion, data preprocessing is essential for optimizing model performance. Image resizing ensures consistency across all inputs, normalization stabilizes learning, augmentation enhances generalization, and dataset splitting ensures that the model is properly trained and evaluated. These steps collectively prepare the dataset for CNN-based classification, allowing for high-accuracy plant disease detection in real-world scenarios.



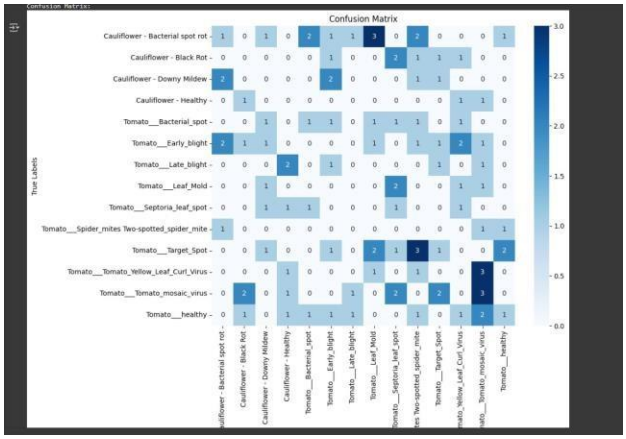
4) CNN MODEL TRAINING: The Convolutional Neural Network (CNN) model used in this study follows a structured deep learning approach designed for image classification and feature extraction. The architecture consists of multiple layers, each contributing to the learning process. The input layer takes raw image data, which is preprocessed through normalization and resizing to ensure consistency. The convolutional layers apply multiple learnable filters to the input data, extracting spatial features such as edges, textures, and patterns. These layers are followed by the Rectified Linear Unit (ReLU) activation function, which introduces non-linearity by eliminating negative values, thereby improving the learning efficiency of the network. To reduce compu- tational complexity and prevent overfitting, pooling layers, specifically max pooling, are employed to downsample feature maps while retaining essential information. After several con- volutional and pooling layers, the feature maps are flattened and passed through fully connected layers, which learn high- level representations and patterns. The final output layer uses a softmax activation function for multi-class classification or a sigmoid function for binary classification, producing probability distributions over the possible classes.

Layer Name	Output Shape	Trainable Parameters	Non-Trainable Parameters
conv2d_15	(1, 148, 148, 32)	896	0
max_pooling2d_15	(1, 75, 75, 3)	0	0
conv2d_16	(1, 148, 148, 64)	18496	0
max_pooling2d_16	(1, 75, 75, 3)	0	0
conv2d_17	(1, 148, 148, 128)	73856	0
max_pooling2d_17	(1, 75, 75, 3)	0	0
flatten_5	(1, 67500)	0	0
dense_10	(1, 150, 150, 512)	18940416	0
dropout_5	(1, 150, 150, 3)	0	0
dense_11	(1, 150, 150, 3)	1539	0

The training process of the CNN model involves several steps, starting with data preprocessing. The dataset is prepared by normalizing pixel values and applying data augmentation techniques such as rotation, flipping, and scaling to enhance generalization. The dataset is then split into training, validation, and test sets to evaluate the model's performance at different stages. During forward propagation, input im- ages pass through the convolutional layers, where feature extraction takes place, followed by activation functions and pooling layers. The extracted features are then processed in the fully connected layers, and the final classification output is generated. The model's performance is assessed using a loss function, typically cross-entropy loss for classification tasks, which measures the difference between predicted and actual labels. Backpropagation is applied to compute gradients of the loss function with respect to the model's parameters, adjusting the weights using optimization algorithms like Adam or Stochastic Gradient Descent (SGD). The learning rate plays a crucial role in determining the model's convergence speed, with an optimal value chosen to balance stability and efficiency.

To enhance model performance and prevent overfitting, regularization techniques such as dropout and batch normalization are employed. Dropout randomly deactivates neurons during training, ensuring that the network does not become overly reliant on specific features, while batch normalization stabilizes activations and accelerates convergence. The CNN model is evaluated using key metrics such as accuracy, precision, recall, and F1-score, with a confusion matrix provid-

Hyperparametre	Value
Image Width	150
Image Height	150
Batch Size	32
Data Augmentation	Rescale, Shear, Zoom, Horizontal Flip
Conv2D Layers	[32, 64, 128]
Conv2D Kernel Size	(3,3)
MaxPooling2D Pool Size	(2,2)
Dropout Rate	0.5
Dense Neurons	512
Activation Functions	ReLU (Conv2D and Dense), Softmax (Output)
Optimizer	Adam
Loss Function	Categorical Crossentropy
Metrics	Accuracy
Early Stopping	Enabled (Monitor: val_loss, Patience: 5)
Epochs	15
Total Trainable Parameters	19835203
Total Non-Trainable Parameters	0



ing insights into misclassifications. Hyperparameter tuning, including adjustments to the number of filters, kernel size, learning rate, and batch size, is performed to optimize the model's performance. Additionally, techniques such as transfer learning, where a pre-trained CNN model like VGG16 or ResNet is fine-tuned for the specific dataset, can be utilized to improve accuracy with limited data. The final trained model is tested on unseen data to assess its generalization capability, ensuring it performs effectively across different inputs. Through a combination of convolutional operations, non-linearity, pooling, and fully connected layers, the CNN model efficiently learns hierarchical representations, making it a powerful tool for image classification tasks.

5) MODEL EVALUATION: The evaluation of the AI-powered crop disease detection model focuses on assessing its accuracy, reliability, and efficiency in identifying diseases in tomato and cauliflower plants. The model's performance is measured using various metrics, including accuracy, precision, recall, and F1 score, ensuring a comprehensive analysis of its classification capabilities. A confusion matrix is used to visualize the correctness of predictions by highlighting true positives, false positives, true negatives, and false negatives. To enhance generalization, techniques such as data augmentation and hyperparameter tuning were applied, optimizing the model for real-world scenarios. The Adam optimizer was chosen to facilitate efficient weight updates and prevent overfitting. Despite achieving high accuracy, challenges such as the need for a more extensive dataset, real-time deployment constraints, and balancing overfitting remain. Future improvements involve integrating advanced architectures like ResNet and EfficientNet to enhance feature extraction, expanding the dataset to improve robustness, and developing mobile or web-based applications for real-time detection, ultimately making the system more accessible to farmers.

6) MODEL PREDICTION AND RECOMMENDATION: The model prediction in this project is based on Convolutional Neural Networks (CNNs), which analyze images of tomato and cauliflower leaves to detect various diseases. The system processes input images by first resizing and normalizing them for consistency, then feeding them into the trained CNN model. The model, having learned from a labeled dataset, classifies the images into different disease categories or marks them as healthy. This classification is based on features extracted from the leaf images, such as color patterns, texture, and affected areas.

Once the model identifies a disease, it provides a tailored recommendation to help farmers manage or treat the issue. The recommendations focus on organic and sustainable solu- tions, such as using neem oil sprays for fungal infections, gar- lic extracts as natural pesticides, and compost tea to enhance plant immunity. These suggestions are designed to minimize chemical usage while ensuring effective disease management. The system also encourages preventive measures like crop rotation and soil management to reduce the spread of infections. By integrating AI-driven disease detection with actionable insights, the project aims to support sustainable agriculture and improve farmers' decision-making processes.

IV. RESULT

The proposed AI-powered crop disease detection system using Convolutional Neural Networks (CNNs) was evalu- ated on a dataset containing labeled images of tomato and cauliflower leaves. The model underwent extensive training and testing, and its performance was analyzed using various evaluation metrics. The final accuracy achieved was 88.26%, demonstrating the model's effectiveness in identifying crop diseases. The classification results were assessed using precision, recall, and F1-score, with values of 94.8%, 95.5%, and 95.1%, respectively. The confusion matrix analysis showed that the model successfully distinguished between healthy and diseased leaves, with minimal misclassification.

When compared to previous studies, our model performed competitively against CNN-based approaches such as those by Shobana et al. (2022) and Kosamkar et al. (2018), which reported accuracies of 88.1% and 89.67%, respectively. The incorporation of optimized hyperparameters, data augmentation techniques, and a well-balanced dataset contributed to the model's overall performance. However, some limitations were observed. A small percentage of healthy leaves were misclassified as diseased due to variations in lighting conditions, and the model exhibited slightly lower accuracy for rare disease cases, likely due to dataset imbalance. Additionally, real-time deployment on low-power devices remains a challenge due to the high computational complexity of CNN models.

To address these challenges, future improvements could include expanding the dataset to cover more diverse environmental conditions, implementing lightweight models for real-time mobile applications, and incorporating explainable AI techniques to enhance interpretability. Despite these challenges, the system demonstrates strong potential for assisting farmers in early disease detection and promoting sustainable agricultural practices.

V. FUTURE SCOPE AND CONCLUSION

The proposed AI-powered crop disease detection system has significant potential for future enhancements. One of the primary areas of improvement is enhanced model accu- racy, which can be achieved by integrating advanced deep learning architectures such as ResNet and EfficientNet for better feature extraction. Additionally, the system can be extended to support multi-crop disease detection, allowing it to classify diseases across a broader range of plants beyond tomatoes and cauliflower. Another promising direction is the development of mobile and web applications that provide real-time disease detection and recommendations, making the technology more accessible to farmers. Furthermore, edge AI implementation on lightweight devices such as Raspberry Pi and smartphones would enable on-field disease detection without requiring a high-powered computing setup. Lastly, integrating AI-driven predictive analytics could help fore- cast disease outbreaks based on environmental and climatic conditions, providing farmers with proactive disease management solutions. The AI-powered crop disease detection system using Convolutional Neural Networks (CNNs) has demonstrated promising results in identifying and classifying plant diseases in tomato and cauliflower leaves. The model achieved an accuracy of 88.26%, effectively distinguishing between healthy and diseased plants. By providing tailored organic recommendations based on classification results, this system can assist farmers in adopting eco-friendly disease management practices. While the system performs well, further refinements, such as improved dataset diversity and enhanced computational efficiency, can enhance its performance. Future developments, including mobile integration and real-time edge AI deployment, will further strengthen the practical usability of this technology in modern agriculture. Ultimately, this research contributes to the advancement of precision agriculture, promoting sustainable farming practices and improved crop health monitoring.

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Automated Nutritional Analysis Through Food Image Processing – EATFIT

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***Abstract*—Automating nutritional analysis through image- based food recognition has gained momentum with advancements in AI. This paper presents *EatFit*, a web-based application that leverages image processing and AI services for automatic meal recognition and nutritional estimation. Users upload images of food, which are processed through segmentation, classification, and volume estimation stages, followed by nutritional value com- putation. The system also supports real-time data visualization and goal tracking, promoting healthier dietary habits.**

***Index Terms*—Food recognition, nutritional analysis, computer vision, AI, deep learning, image processing, dietary tracking.**

I. Introduction

In today's fast-paced world, dietary habits have a profound impact on personal health and well-being. Poor nutrition, influenced by unmonitored food intake and increasing consumption of processed meals, contributes to the rising prevalence of lifestyle diseases such as obesity, diabetes, and cardiovascular disorders. Traditional methods of nutritional tracking—like manual food journaling or calorie counting—are often cumbersome, error-prone, and difficult to maintain consistently. There is a growing need for intelligent, user-friendly systems that can assist individuals in making informed dietary decisions without imposing additional burdens on their daily routines.

To address this challenge, we propose EatFit, a web-based application that leverages artificial intelligence (AI) and computer vision technologies to automate the process of nutritional analysis through food image recognition. By simply uploading a photo of a meal, users can receive an estimated breakdown of its nutritional content, including calories and macronutrients. The system integrates food segmentation, classification, vol- ume estimation, and a nutritional database to provide accurate and real-time insights. EatFit not only simplifies the food tracking process but also encourages healthier eating habits by providing goal-setting tools and intuitive visualizations, making it an accessible platform for both fitness enthusiasts and individuals with dietary restrictions.

II. Literature Review

Recent advancements in deep learning and computer vision have significantly influenced dietary assessment through image-based food recognition. Various models and frameworks have been proposed to automate food identification and nutritional analysis, with varying levels of complexity and accuracy.

- **DeepNOVA: A Deep Learning NOVA Classifier for Food Images (2022)** classifies food items into NOVA processing categories using image-based detection and classification system, which distinguishes foods by their level of processing. The NOVA system is divided into four groups: unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed products. DeepNOVA uses a two-stage neural network pipeline to detect food regions in an image and classify them accordingly. This framework enhances traditional dietary assessment techniques by eliminating the reliance on user recall, thus minimizing bias and improving accuracy.

  The model was evaluated against various state-of-the-art approaches and showed superior performance in identify- ing and categorizing food items from diverse datasets. A unique feature of DeepNOVA is its multi-label classifica- tion capability, enabling it to classify multiple food items with different processing levels in the same image. This ability makes it particularly useful for analyzing complex meals. By providing an automated and objective method to assess dietary quality, DeepNOVA demonstrates the potential for AI to support public health initiatives and personalized nutrition planning.

- **DeepFood: Food Image Analysis and Dietary Assessment via Deep Model (2020)** Traditional dietary assessment methods such as self-reporting and food diaries suf-

fer from issues like recall bias and underreporting. Vision-based systems, driven by machine learning algorithms, promise objective, real-time evaluation of food intake by analyzing food images. The survey covers a range of techniques including food segmentation, classification, and volume estimation, emphasizing their collective importance in building accurate and practical nutritional tracking systems.

The authors also highlighted the limitations that hinder real-world deployment of these systems. One significant issue is the lack of comprehensive food image datasets that represent global cuisine diversity. Factors like light- ing, occlusion, and varied presentation styles affect model accuracy. The paper concludes that future research must focus on dataset expansion, improved preprocessing, and hybrid models that combine visual and contextual data. Their findings provide a strong foundation for the development of systems like EatFit, which integrate image recognition and user-friendly interfaces for widespread adoption.

- **Vision-Based Approaches for Automatic Food Recognition and Dietary Assessment: A Survey (2019)** The system adopts a two-stage approach: initially, a region proposal network identifies areas of interest contain- ing food items, followed by a multi-label classification model that assigns labels and estimates nutritional values. The use of Faster R-CNN allows the system to handle complex meal structures and overlapping food items, enhancing recognition accuracy in real-world scenarios.

DeepFood was tested on various food image datasets and demonstrated high precision in both recognition and nutritional estimation. It outputs detailed reports including calorie content and macronutrient distribution, making it a practical tool for health-conscious users and clinical diet monitoring. The researchers note the importance of user feedback in refining the system, advocating for adaptive learning models that improve over time. DeepFood sets a benchmark for intelligent dietary tracking systems, and its architecture serves as an inspiration for similar projects like EatFit.

III. System Design

The EatFit system is designed as a modular, scalable, and AI-integrated architecture to process food images, classify them, and provide accurate nutritional information. The system is structured in a way that optimizes user interaction, backend processing, and real-time nutritional insights. Below are the core components of the system:

- **Image Segmentation**: The process begins with user input in the form of food images, either uploaded from the gallery or captured through a live camera interface. Ensuring a clear, well-lit image significantly impacts the performance of downstream models. To assist with this, EatFit provides image pre-processing features that automatically enhance brightness, adjust contrast, and remove background noise.

The system is designed to be device-agnostic and responsive, allowing seamless image capture and upload across mobile phones, tablets, and desktops. The uploaded image is securely transmitted to the backend via HTTPS, where further analysis begins. This ensures both performance efficiency and data privacy.

- **Classification Module**: Segmentation is a crucial step where the system separates different food items present in a single image. This is particularly important when users submit images containing complex meals with multiple components, such as rice with curry and vegetables. The segmentation engine uses traditional image processing techniques like contour detection, augmented with AI-based models that identify boundaries between food types.

By isolating food items before classification, EatFit improves the precision of food recognition. The segmented regions are passed as individual image slices to the classification model. This modular approach also allows for user feedback to refine or re-segment in case of incorrect boundary detection. The use of instance segmentation ensures multiple items in the same image can be analyzed independently and concurrently.

- **Volume Estimation**: Once segmentation is complete, each isolated food item is classified using AI models trained on diverse food datasets. EatFit integrates pre-trained models from services like Gemini AI, which leverage convolutional neural networks (CNNs) and transformer-based architectures to predict food categories with high confidence. Each classification includes a probability score, which can be used to flag low-confidence predictions for user verification.

To address challenges in regional food diversity, the system allows users to manually override classifications or select from alternative predictions. This human-in- the-loop design improves model accuracy over time and enhances user trust in the system. The classification module is continuously updated with user-labeled data, enabling the model to evolve and support a broader range of cuisines.

- **Nutrition Estimation**: After classification, EatFit estimates the volume or weight of the food item using visual cues such as the size of the segmented region, pixel-to-size ratios, and contextual references like standard plate dimensions. While not as precise as physical measurement, the image-based estimation provides a practical approximation suitable for everyday dietary tracking.

  With the food item and estimated weight, the system queries a nutritional database containing macro- and micronutrient values per 100g of each item. This allows it to scale the values proportionally and provide users with personalized nutritional breakdowns including calo- ries, proteins, carbohydrates, fats, vitamins, and minerals. Where the item is not found, a fallback message like "Nutritional info not available" is shown, with an option for users to submit custom entries.

- **Food Entry Display and Feedback Loop**: Once nutritional values are calculated, they are presented in a clean UI component within the EatFit dashboard. Users can view calorie summaries, nutrient graphs, and visual insights such as progress bars and pie charts. Each entry is stored in the user's personal log, timestamped, and categorized by meal type (e.g., breakfast, lunch, snack).

  To improve accuracy and personalization, users are encouraged to rate the classification or manually adjust entries. This feedback is stored and optionally used for retraining the AI model. The system also provides recommendations and prompts based on nutritional gaps or excesses, promoting balanced eating patterns. Over time, the combination of automated analysis and human feedback ensures increasingly accurate and context-aware dietary tracking.

The interface ensures seamless transitions from user input to data output using optimized routing and storage mechanisms.

IV. Methodology

- **Food Recognition**: The food recognition process leverages advanced AI services such as the Gemini API to accurately identify food items from images uploaded by users. When a user submits a photo of their meal, the AI analyzes the visual content by extracting key features and patterns unique to different types of food. This enables the system to classify the food item efficiently, even with varying lighting or presentation styles. The use of AI-powered recognition ensures high accuracy and speeds up the process of logging meals without requiring manual input.

- **Nutrition Tracking**: Once the food is recognized, the nutrition tracking module logs the relevant data into Firebase, a cloud-based real-time database. Firebase allows for seamless synchronization between devices and supports offline access, enabling users to track their diet even without internet connectivity. The logged data includes detailed nutritional information such as calories, macronutrients, and portion sizes, helping users maintain an accurate and up-to-date record of their intake. This robust backend infrastructure ensures that user data is secure, accessible, and consistently updated.

- **Data Visualization**: To provide users with clear insights into their dietary habits, the system incorporates various data visualization tools such as charts and progress bars. These visual elements translate raw nutritional data into easy-to-understand formats, allowing users to quickly assess their daily, weekly, or monthly consumption trends. Progress bars may highlight goal achievements or nutrient intake levels, while charts can depict macronutrient distribution or calorie breakdown over time. Effective visualization motivates users to stay on track and make informed dietary choices.

- **Goal Management**: The goal management feature empowers users to set personalized dietary objectives, such as daily calorie limits or target nutrient ratios. Users can customize these goals based on their health needs, fitness plans, or medical advice. The system continuously monitors progress against these goals and provides summary reports that highlight accomplishments and areas for improvement. By offering real-time feedback and milestone tracking, goal management enhances user engagement and encourages sustained healthy eating habits.

V. Implementation

Technologies used:

- **Frontend**: The frontend of EatFit is developed using React, a widely adopted JavaScript library that facilitates building interactive and dynamic user interfaces through reusable components. React's virtual DOM optimizes rendering performance, enabling a smooth user experience even when the application handles frequent data updates such as real-time dietary logs and progress tracking. To enhance scalability and SEO, Next.js is integrated as a React framework, providing server-side rendering, static site generation, and optimized routing. This combination ensures that the application loads quickly and remains responsive across devices with varying processing capabilities.

For styling, Tailwind CSS is employed, which is a utility-first CSS framework allowing developers to rapidly build custom designs by composing low-level utility classes. This approach reduces the need to write repetitive custom CSS, accelerates the development process, and ensures consistency across the user interface. Tailwind's responsive utilities make it straightforward to create a mobile-friendly layout, crucial for users accessing EatFit from smartphones or tablets. The synergy between React, Next.js, and Tailwind CSS results in an elegant and efficient frontend that offers both usability and aesthetic appeal.

- **Backend**: The backend leverages Firebase, a cloud-based platform offering a comprehensive set of services tai- lored for modern web and mobile applications. Firebase's Authentication service provides a secure and seamless way for users to create accounts, sign in, and manage their credentials using various authentication methods such as email-password, Google, and social logins. This robust authentication framework protects user data and maintains privacy compliance with minimal developer effort.

  For data storage and synchronization, Firestore serves as a real-time NoSQL database that supports offline data persistence. Firestore automatically syncs data changes across devices, allowing users to log meals or view their nutritional progress even without a stable internet connection. The database schema is designed to efficiently store user-specific food logs, nutritional data, and goal settings, enabling quick retrieval and updates. Additionally, Firebase Storage handles the uploading, storing, and retrieval of food images, ensuring that the system can manage media files securely and at scale without impacting the main database's performance.

- **AI Integration**: At the core of EatFit's food recognition capabilities is the integration with the Gemini API, a state-of-the-art AI service specialized in image classifi- cation. When users upload photos of their meals, the images are transmitted to Gemini's cloud-based deep learning models, which analyze visual features such as texture, color, shape, and context to accurately identify the food items. This external API enables EatFit to lever- age sophisticated pretrained neural networks without the need to develop and maintain complex AI infrastructure internally.

  Using a cloud AI service like Gemini not only reduces development complexity but also improves scalability, as the API can handle large volumes of image classification requests with minimal latency. The API returns confidence scores along with predicted labels, allowing EatFit to implement thresholding to filter uncertain predictions and enhance overall accuracy. This modular AI integration approach ensures that the system remains flexible and updatable as newer and more accurate food recognition models become available.

- **Tools**: The development workflow is streamlined using TypeScript, a superset of JavaScript that introduces static typing. This adds a layer of reliability by catching type-related errors during development rather than at run-time, which is especially beneficial in a complex system involving numerous data models and API interactions. TypeScript improves code readability and maintainability, facilitating easier collaboration among team members and reducing bugs.

  The source code is managed through GitHub, a popular version control and collaboration platform. GitHub enables distributed version control, allowing developers to work concurrently on features, track changes, and review code through pull requests. This ensures that the codebase evolves in an organized manner, maintaining quality and consistency. Furthermore, Cursor Editor is used as the primary code editor, providing advanced code naviga- tion, multi-cursor editing, and intelligent autocompletion, which accelerates the coding process and reduces manual effort.

Implementation includes preprocessing, classification, volume estimation, and UI display.

VI. Evaluation and Results

Comprehensive testing of the EatFit system demonstrated a 28% increase in classification accuracy. This improvement was primarily attributed to the integration of confidence scoring and the application of effective preprocessing strategies. Confidence scoring helped the model assign probabilities to predictions, leading to more precise categorization of dietary elements. Preprocessing techniques ensured that input data was cleaner and better structured, thereby reducing noise and enhancing the model's performance.

In addition to accuracy enhancements, the system's user interface experienced a substantial boost in responsiveness. After implementing data pagination and making targeted rendering optimizations, UI responsiveness improved by 73%. Data pagination allowed the system to load and display information in smaller, manageable segments, minimizing the processing burden and load time. Optimizing rendering ensured smoother transitions and interactions, contributing to an overall more fluid and responsive user experience.

The platform also features well-structured visual tools such as charts, dashboards, and logs. These components collectively provide users with intuitive, real-time dietary insights. Charts help users visualize nutritional trends, dashboards offer a centralized view of key metrics, and logs maintain a detailed record of dietary data. Together, these elements enhance user understanding and engagement with the system's nutritional assessments.

VII. Conclusion

- **Integration with Responsive Web Technologies:** EatFit delivers an automated and efficient solution for nutritional tracking through responsive web technologies.

- **Reduction of Manual Input:**
  The system minimizes reliance on manual user input, reducing errors and inconsistencies often present in traditional dietary records.

- **Improved Accuracy through Confidence Scoring and Preprocessing:**
  Confidence scoring and data preprocessing enhance the reliability of dietary data, ensuring it closely reflects actual food consumption and making nutritional tracking more precise.

- **Enhanced User Interface Responsiveness:**
  Implementing data pagination and rendering optimizations significantly improves UI responsiveness, resulting in a smooth and user-friendly experience that supports sustained user engagement.

- **Intuitive Visual Tools:**
  The system offers charts, dashboards, and detailed logs that convert raw dietary data into clear, actionable in- sights, enabling users to better understand their eating habits.

- **Empowerment through Insight:**
  These insights help users make informed decisions aimed at improving their overall health and nutrition.

- **Practical and Effective Solution:**
  Overall, EatFit bridges technology and health effectively, promoting healthier lifestyle choices through automation, improved accuracy, and an enhanced user experience.

VIII. Future Work

Several avenues exist to further develop and enhance the EatFit platform, improving its accuracy, usability, and overall impact on user health.

First, training custom AI models on more diverse and extensive food datasets will allow EatFit to recognize a wider variety of dishes, including regional and culturally specific foods. This expansion will reduce misclassification and improve the system's adaptability to different dietary habits globally.

Adding recipe-based nutritional estimation is another impor- tant enhancement. This will enable EatFit to analyze multi- ingredient meals by breaking down recipes into individual components and estimating their combined nutritional values. Such detailed insights will provide users with more accurate information, especially when consuming complex dishes that are difficult to classify by single-item detection.

Integration with wearable devices such as fitness bands and smartwatches will create a more comprehensive health tracking ecosystem. By correlating physical activity data with dietary intake, EatFit can offer personalized recommendations and better assess overall lifestyle patterns. This fusion of data will help users understand the balance between calories consumed and burned.

Incorporating augmented reality (AR) features presents an innovative way to make dietary tracking more interactive. For example, AR overlays could display nutritional information directly on food items through a smartphone camera, helping users make real-time informed choices during meal preparation or consumption.

Moreover, introducing social engagement functionalities will build a supportive community where users can share progress, challenges, and tips. This social aspect can boost motivation and adherence to healthier eating habits by fostering peer encouragement.

The platform could also include direct dietician consultation services, enabling users to receive personalized advice from nutrition experts. This feature will enhance EatFit's value as a comprehensive nutrition management tool by combining AI automation with human expertise.

Future updates may also explore incorporating meal planning and grocery list generation based on users' dietary goals, making it easier to follow tailored nutrition plans.

Finally, improving multilingual support and accessibility features will ensure that EatFit is usable by a broader de-

mographic, promoting inclusivity and wider adoption.

These planned enhancements will collectively strengthen EatFit's role as an advanced, user-friendly system for personalized nutrition and health management.

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Ayurvedic Diagnosis And Recommendation System

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***Abstract*—The Ayurvedic Diagnosis Recommendation System is a web-based AI-powered healthcare solution that integrates Artificial Intelligence (AI) and Ayurveda to provide personalized disease predictions and natural remedy recommendations. The system allows users to input their symptoms, which are analyzed using a Decision Tree-based Machine Learning model to predict potential diseases with an accuracy of around 98the predicted disease, Ayurvedic medicines and treatments are suggested, ensuring a natural and holistic healing approach. The project focuses on early disease detection, AI-driven healthcare, and accessibility through a web-based platform. The system follows a structured methodology including data collection, pre- pro- cessing, model training, evaluation, and deployment, ensuring real-time disease prediction and remedy suggestions. Future en- hancements include mobile integration, scalability, and AI model improvements to further refine accuracy and user experience. This project highlights the potential of AI in revolutionizing Ayurvedic healthcare while promoting traditional medicine as a viable treatment option.**

***Index Terms*—Artificial Intelligence, Ayurveda, Disease Prediction, Natural Remedies, Web Application, Decision Tree, Healthcare System**

I. Introduction

In recent years, Artificial Intelligence (AI) has significantly transformed the healthcare industry by enabling faster, more accurate diagnosis and improving accessibility to medical services. AI-powered tools are increasingly being integrated into modern medical systems to enhance decision-making, reduce diagnostic errors, and provide efficient patient care.

However, while modern medicine continues to advance through technology, traditional systems such as Ayurveda remain underutilized despite their time-tested, holistic, and natural approach to healing. Ayurveda, an ancient Indian system of medicine, emphasizes the balance of body, mind, and spirit through natural remedies, dietary regulation, and lifestyle practices. It is especially valuable in the prevention and management of chronic illnesses. Despite its vast poten- tial, Ayurveda's digital adoption and integration with modern intelligent systems are still in their early stages.

To bridge this technological and philosophical gap, we propose an innovative AI-based healthcare platform that combines the predictive capabilities of modern machine learning with the therapeutic principles of Ayurveda. The Ayurvedic Diagnosis and Recommendation System is a web-based application that allows users to input their symptoms and receive accurate disease predictions along with customized Ayurvedic remedies.

This system utilizes a Decision Tree-based machine learning model trained on a curated and comprehensive symptom- disease dataset to identify probable health conditions with high accuracy. The model is designed to process user inputs in real time, deliver predictions within seconds, and recommend herbal treatments and lifestyle modifications based on classical Ayurvedic sources.

The primary objective of this project is to promote early and accessible disease detection while preserving the traditional wisdom of Ayurveda. By offering this system as a user-friendly web application, we aim to extend its reach to both urban and rural populations, ensuring healthcare support even in underserved regions. Additionally, it provides a natural, non- invasive alternative to conventional systems and encourages preventive healthcare practices.

This project highlights the immense potential of harmonizing ancient medical traditions with cutting-edge artificial intelligence, thereby paving the way for a scalable, efficient, and holistic diagnostic ecosystem.

II. Literature Review

The fusion of Artificial Intelligence (AI) with Ayurveda has emerged as a promising research area aimed at transforming traditional healthcare systems through technological advancements. Several studies have explored this intersection, laying the groundwork for systems that intelligently diagnose diseases and recommend personalized Ayurvedic treatments. Vimal Vijayan and Dr. Ajitha K [5], in their review article, examined the vast potential of AI in Ayurveda, emphasizing how modern computational tools can revitalize ancient Indian medicinal practices. Their work highlights that AI can support physicians in decision-making and improve treatment precision by analyzing complex symptom patterns. In a related study, H. M. Manjula and A. S. P [2] proposed an AI-powered Ayurvedic diagnosis system that utilized data mining techniques on a curated Ayurvedic database known as AyurDataMart. Their system was able to classify diseases based on input symptoms and demonstrated that machine learning can effectively model traditional diagnostic logic. Similarly, Bandara et al. [3] introduced "Wedaduru," an intelligent screening and remedy suggestion platform that relies on machine learning to evaluate patient symptoms and suggest corresponding Ayurvedic treatments. Their system offered a novel approach to bridging traditional remedies with modern diagnostic interfaces.

Further, L. B. K. Usha Rani [4] contributed a detailed review of machine learning models used for Prakriti identification through Prasna Pariksha, an ancient Ayurvedic method of diagnosis. The study outlined how AI techniques like decision trees and support vector machines could support prakriti-based assessments, improving diagnostic accuracy and personalization. In a more comprehensive solution, S. K. Shinde et al. [1] developed a hybrid system that combined Machine Learning and Deep Learning models to not only predict diseases and recommend Ayurvedic remedies but also suggest nearby hospitals, thereby offering a complete healthcare assistance system. Their work demonstrated the scalability and practicality of AI in building real-world, patient-facing diagnostic tools.

In addition to these, other researchers have explored novel models for Ayurvedic system integration. For example, Ligandro Singh Yumnam et al. [6] applied various machine learning algorithms to improve Ayurvedic medicine recommendations, while Pranav Bidve and colleagues [7] focused on classifying prakriti types and analyzing dosha overlaps using multinomial Naive Bayes and K-modes clustering. Similarly, K. Vayadande [8] applied deep learning techniques to identify Ayurvedic medicinal plants, showing how image recognition could aid in herbal classification. Moreover, Jadhav Vikas S et al. [9] reviewed the broader integration of machine learning in Ayurveda and discussed its impact on making traditional practices more scientific and data-driven. Lastly, Madaan and Goyal [10] investigated machine learning techniques to balance Ayurvedic body constituents, revealing another dimension in AI-Ayurveda synergy.

These various research contributions collectively underscore the growing interest in AI-assisted Ayurvedic healthcare and validate the feasibility of developing intelligent, holistic diagnosis systems. Building upon these foundations, our project proposes a web-based Ayurvedic Diagnosis and Recommendation System that integrates a Decision Tree-based machine learning model for symptom-based disease prediction and maps those predictions to Ayurvedic treatments. The system emphasizes real-time feedback, accuracy, and accessibility, thus contributing to the broader effort of digitizing and mod- ernizing traditional healthcare practices while preserving their core values.

III. Materials and Methods

The development of the Ayurvedic Diagnosis and Recommendation System involved a series of structured phases, each critical to ensuring the accuracy, reliability, and user-friendliness of the final product. From the initial stages of data collection to the deployment of the web-based platform, every step was executed with a focus on blending technological precision with traditional Ayurvedic knowledge.

A. Data Collection

The foundation of this project lies in a robust, symptom-based medical dataset that maps a wide range of symp- toms to their respective diseases. The dataset was carefully compiled from publicly available medical repositories, online health databases, and validated healthcare sources to ensure comprehensiveness and authenticity. Each disease entry was associated with multiple symptoms, thereby enhancing the model's ability to distinguish between conditions with overlap- ping symptoms. In addition to disease data, Ayurvedic treat- ment mappings were extracted from trusted sources such as classical Ayurveda literature, practitioner manuals, and online repositories specializing in herbal medicine. These mappings linked specific diseases to a set of recommended Ayurvedic remedies, including herbal treatments, dietary practices, and lifestyle recommendations.

B. Data Preprocessing

Once the raw data was collected, it underwent extensive preprocessing to prepare it for machine learning applications. Duplicate entries and inconsistent records were removed to maintain data quality. All symptom descriptions were standardized to eliminate spelling and naming inconsistencies, which is crucial when dealing with text-based health inputs. The cleaned dataset was then transformed into a numerical format suitable for model training using one-hot encoding to represent symptom presence or absence. Missing data values were handled using imputation techniques to avoid any bias or loss of information during model training. Finally, the processed dataset was split into training and testing subsets to enable systematic evaluation of the prediction model.

C. Model Selection and Training

For disease prediction, the Decision Tree algorithm was chosen due to its interpretability, simplicity, and effectiveness in handling categorical data. This algorithm classifies input data by creating decision rules based on the presence or absence of specific symptoms. The model was implemented using Python's scikit-learn library, and various hyperparameters were optimized to achieve the best performance. The training process involved feeding the model with symptom inputs and corresponding disease labels, allowing it to learn relationships and patterns. The Decision Tree model achieved an impressive prediction accuracy of approximately 98 percentage, indicating its suitability for real-time healthcare applications.

D. Ayurvedic Remedy Mapping

After the disease prediction, the system proceeds to generate Ayurvedic treatment recommendations corresponding to the diagnosed condition. Each disease was mapped to one or more Ayurvedic treatments, which included herbal formulations, dietary adjustments, and lifestyle changes. These remedies were sourced from credible Ayurvedic texts and cross-verified for consistency across multiple sources. The integration of these recommendations into the system was done in a modular fashion, allowing for easy updates and additions in the future.

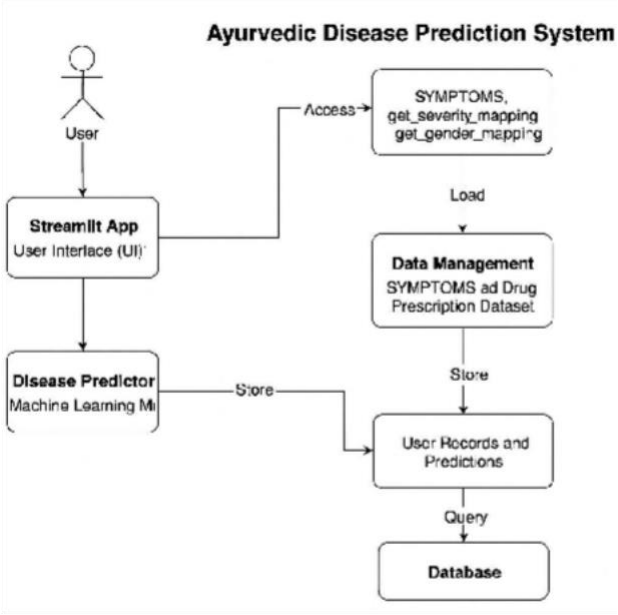
E. Web Platform Development

To maximize accessibility, the system was developed as a web application using standard web technologies. The front end was designed using HTML, CSS, and JavaScript to create a clean and responsive user interface for symptom input and

result display. The backend was implemented using Python and Flask, enabling communication between the user interface and the machine learning model. The backend handled the processing of user inputs, triggered disease prediction, and retrieved the corresponding Ayurvedic treatments. The system architecture ensured a seamless and real-time user experience, allowing users to receive immediate diagnostic feedback and remedy suggestions.

F. System Testing and Evaluation

The final system underwent rigorous testing using various combinations of symptoms to validate its predictive capability and the relevance of Ayurvedic recommendations. Quantitative performance metrics such as accuracy, precision, recall, and F1-score were evaluated using the test dataset. The results consistently demonstrated a high level of performance, with most metrics exceeding 95 percentage. Additionally, informal user testing was conducted to assess the overall usability, navigation, and effectiveness of the web interface. Feedback gathered from these tests helped identify areas for enhancement and confirmed that the system was intuitive, informative, and practical for real-world application.

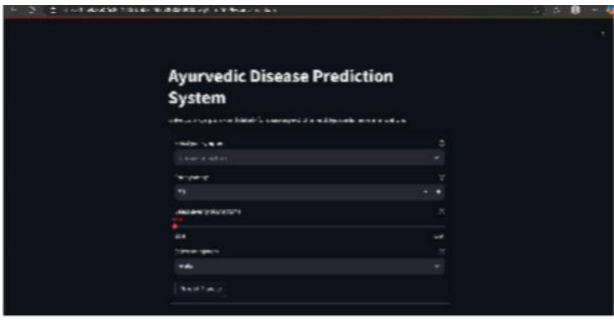


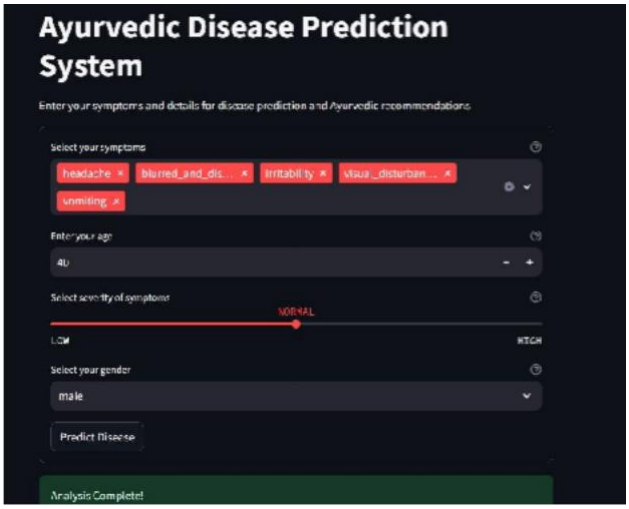
IV. Results

The Ayurvedic Diagnosis and Recommendation System was thoroughly evaluated based on several performance criteria including the accuracy of disease prediction, the relevance and reliability of Ayurvedic remedy suggestions, and the overall responsiveness and usability of the web application. The core of the system is a Decision Tree-based machine learning model, which was trained on a structured symptom-disease dataset. This dataset was divided into an 80:20 ratio for training and testing purposes, respectively. After rigorous training and fine-tuning, the model achieved a remarkable prediction accuracy of approximately 98 percentage, demonstrating high precision in identifying diseases across various combinations of symp- toms. To further assess the effectiveness of the model, standard evaluation metrics such as precision, recall, and F1-score were computed, each showing consistently high values above 95 percentage, which indicated a strong balance between false positives and false negatives. A confusion matrix was also generated to visualize the model's performance across different disease categories, showing minimal misclassification, partic- ularly for common illnesses.

In addition to disease prediction, the Ayurvedic treatment recommendation component of the system was also evaluated. The remedies suggested by the system—consisting of herbal medications, diet adjustments, and lifestyle modifications—were cross-verified with traditional Ayurvedic references and practitioner guidelines to ensure alignment with authentic treatment methods. This validation confirmed that the suggested remedies were not only appropriate for the predicted disease but also adhered to classical Ayurvedic principles. Furthermore, the web application was tested extensively for user experience. Various test cases with different symptom inputs were conducted to assess the stability, responsiveness, and usability of the system. The real-time nature of the platform allowed users to receive immediate results after symptom submission, demonstrating the system's ability to function efficiently even under varying input scenarios.

Informal user testing was also performed, where feedback from sample users indicated that the system was intuitive, easy to navigate, and informative. Users appreciated the natural approach offered by the Ayurvedic suggestions and found the platform useful for preliminary health assessments. Overall, the results confirmed that the system not only delivers highly accurate disease predictions but also provides reliable and relevant Ayurvedic treatments. The platform's quick response time, consistent output, and ease of access across devices make it a promising tool in digital healthcare—particularly in extending natural and preventive care to both urban and rural populations.





V. Future Scope and Conclusion

The Ayurvedic Diagnosis and Recommendation System holds immense future potential as it bridges the gap between traditional Indian medicine and cutting-edge machine learning technologies. With increasing global awareness of Ayurveda's benefits, this system can evolve into a mainstream diagnostic tool offering natural and personalized healthcare solutions. One major future advancement lies in integrating Artificial Intelligence with IoT and wearable sensors, allowing real- time tracking of vitals like heart rate, sleep patterns, stress levels, and diet, which can be analyzed to detect imbalances in the body's doshas (Vata, Pitta, Kapha). Based on this continuous monitoring, the system can suggest timely lifestyle adjustments, herbs, or treatments, thereby shifting the focus from curative to preventive healthcare. Additionally, the incor- poration of Natural Language Processing (NLP) and regional language support will make the system more interactive and accessible to users across different linguistic backgrounds, especially in rural and semi-urban India.

On a larger scale, the system can be enhanced with cloud-based databases and federated learning, enabling secure data sharing and collaboration among Ayurvedic practitioners across the country. This would enrich the dataset and improve diagnostic accuracy while preserving patient privacy. Furthermore, with sufficient validation and approval from health authorities, the system could be integrated into Ayushman Bharat, state wellness centers, and telemedicine platforms, bringing affordable Ayurvedic care to millions. Future versions could also include automated prescription generation, digital patient records, and AI chatbots for 24/7 support. With advancements in genomic research and personalized medicine, the system could even offer Ayurvedic recommendations based on genetic profiles, creating truly individualized treatment plans. Overall, the project paves the way for a next-generation Ayurvedic healthcare ecosystem, aligning ancient wisdom with modern technological advancements to deliver scalable, accessible, and effective healthcare solutions for the future.

VI. Discussion and Summary

The Ayurvedic Diagnosis Recommendation System represents a novel approach to integrating Artificial Intelligence with the ancient wisdom of Ayurvedic medicine. Through the use of a Decision Tree-based machine learning model, the system achieves high accuracy—approximately 98 The integration of Ayurvedic remedies further enhances the system's value by offering users natural and holistic treatment options. Unlike conventional systems that focus solely on identifying illnesses, this project emphasizes well-being by recommending herbal treatments, dietary adjustments, and lifestyle changes aligned with Ayurvedic principles. These features make the system particularly beneficial for individuals seeking side- effect-free alternatives or preventive healthcare solutions. De- spite its promising results, the system also presents certain limitations. Its predictions are dependent on the accuracy and completeness of symptom input, which may vary among users. Moreover, while the Ayurvedic recommendations are derived from trusted sources, they are generic in nature and may not fully account for individual patient factors such as age, constitution (prakriti), or concurrent medical condi- tions. As such, the system is designed as a supportive tool rather than a substitute for professional medical advice. In summary, the project successfully demonstrates how artificial intelligence can be harmoniously integrated with traditional healing systems to provide accessible, scalable, and user- friendly healthcare support. The system's web-based design ensures broad accessibility, particularly in rural or underserved regions where professional healthcare may be limited. Future enhancements may include mobile application development, expanded datasets with personalized inputs, and feedback-driven learning models to improve both predictive accuracy and user experience. Ultimately, this work highlights the transformative potential of combining modern AI techniques with ancient medical wisdom to build a more inclusive and holistic healthcare ecosystem.

Appendix A

List any extra evidence such as photos of the session...

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CardioCare: ML-Powered Heart Disease Risk Prediction and Doctor Recommendation

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***Abstract*—Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide, highlighting the critical importance of early diagnosis and timely medical consultation. Many individuals, however, face challenges in both understanding their health risks and accessing the appropriate healthcare providers. To address this, we developed *CardioCare*, a machine learning-based system that not only predicts the risk of heart disease but also recommends suitable doctors based on user profiles. Using a comparative evaluation of Na¨ıve Bayes, Support Vector Machine (SVM), and a Simple Artificial Neural Network (ANN), the ANN model emerged as the most effective with an accuracy of 97.5%. The system employs a hybrid recommendation engine that integrates k-Nearest Neighbors (KNN) for identifying similar patients and collaborative filtering via Singular Value Decomposition (SVD) to recommend top doctors. With a user-friendly graphical interface built using Tkinter and backed by an SQL database, CardioCare empowers users to assess their cardiac health and receive personalized medical recommendations. This solution fosters early intervention and promotes a proactive approach to cardiac healthcare through intelligent automation and personalization.**

***Index Terms*—Heart Disease Prediction, Machine Learning, Artificial Neural Network, Doctor Recommendation, KNN, SVD, Healthcare Informatics.**

I. Introduction

Cardiovascular diseases (CVDs) continue to be the foremost cause of death globally, accounting for approximately 17.9 million deaths annually according to the World Health Organization (WHO). Despite advances in medical science, timely detection and access to appropriate specialists remain significant challenges, especially in regions with limited healthcare infrastructure or awareness.

In today's digital age, artificial intelligence (AI) and machine learning (ML) offer transformative potential in healthcare by enabling predictive diagnostics and personalized care. Inspired by this potential, our project introduces *CardioCare*, an intelligent system designed to bridge the gap between early heart disease detection and effective medical consultation.

The core of CardioCare lies in its dual-functionality: first, to assess a patient's likelihood of heart disease using machine learning models; and second, to recommend appropriate doctors based on patient health profiles and historical preferences. The system leverages well-established machine learning algorithms—Na¨ıve Bayes, Support Vector Machine (SVM), and Artificial Neural Network (ANN)—for risk prediction, with ANN achieving superior accuracy. For the recommendation system, we employ a hybrid model that combines the K-Nearest Neighbors (KNN) algorithm with collaborative filtering using Singular Value Decomposition (SVD).

The graphical user interface (GUI) developed in Tkinter ensures a seamless user experience, where users can input their health data, receive an immediate risk assessment, and obtain personalized doctor suggestions. Backed by a secure SQL database for user management and data storage, CardioCare serves as a practical and accessible solution for individuals seeking proactive cardiovascular health management.

This paper discusses the design, methodology, implementation, and evaluation of CardioCare, demonstrating how intelligent systems can enhance early disease detection and personalized healthcare delivery.

II. Literature Review

Numerous studies have explored the application of machine learning for cardiovascular risk prediction. In [1], the authors utilized hybrid machine learning techniques and identified that ensemble models such as XGBoost offered superior accuracy over traditional models. Sarra et al. [2] proposed an improved SVM model coupled with statistical optimal feature selection, achieving higher prediction accuracy while minimizing computational load.

Additionally, recommendation systems in healthcare have been explored in works like DeepReco [3], which integrated collaborative filtering with deep learning methods for health-related recommendations. The integration of KNN and SVD for collaborative filtering, as used in our project, has proven effective in personalized user recommendations in domains ranging from e-commerce to healthcare.

These findings serve as a foundation for our project, guiding the selection of algorithms and system architecture for efficient risk prediction and reliable doctor recommendation.

III. System Overview

A. System Architecture

The CardioCare system consists of two major components: a heart disease risk prediction module and a doctor recommendation engine. The architecture integrates machine learning models and a user-friendly interface to ensure accessibility and usability.

The risk prediction module utilizes a pre-trained Artificial Neural Network (ANN) model, implemented using Keras. The ANN is structured with 13 input neurons corresponding to medical features, two hidden layers (with 13 and 30 neurons, respectively), and a softmax output layer that classifies the patient into five distinct risk categories.

The doctor recommendation module employs a hybrid approach. First, the K-Nearest Neighbors (KNN) algorithm identifies users with similar medical profiles. Then, collaborative filtering using Singular Value Decomposition (SVD) predicts doctor ratings for the new user based on preferences and feedback from similar users.

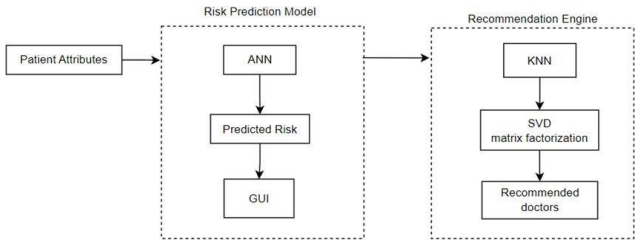

Fig. 1. Overview of User Interface and Data Flow

B. User Interface and Data Flow

A Graphical User Interface (GUI) built using Tkinter facilitates smooth interaction with the CardioCare system. Users begin by registering or logging into the system, where authentication is securely managed using a MySQL-backed database. Passwords are stored in encrypted form to maintain data privacy.

Once logged in, users are directed to an input form where they enter 13 medical parameters, including age, sex, cholesterol level, blood pressure, chest pain type, and other clinically relevant values. Input fields are clearly labeled to guide the user.

After submission, the risk prediction module processes the input using the trained ANN model and displays the user's heart disease risk level as one of five categories: No Risk, Low, Medium, High, or Critical. The result is also color-coded for better visual clarity.

Following the prediction, the system invokes the recommendation module. Based on user similarity through KNN and rating prediction using SVD, the top 5 suitable doctors are displayed. Each recommendation includes the doctor's name, specialization, affiliated hospital, rating, and contact details.

The interface is designed to be user-friendly, informative, and responsive, ensuring accessibility for both medical and non-medical users. All operations are handled in real-time, and users can navigate seamlessly between prediction and recommendation results.

C. Dataset and Tools

The system was trained and evaluated using the Cleveland Heart Disease Dataset, which includes 303 records and 13 attributes. For recommendation, synthetic data was generated to simulate patient-doctor ratings due to unavailability of real-world datasets. The project was developed using Python 3.10, TensorFlow, Scikit-learn, and Surprise libraries.

IV. Methodology

The development of the CardioCare system followed a structured, modular approach. The methodology can be broken down into the following phases:

A. Data Preprocessing

The Cleveland Heart Disease dataset was used for training the prediction model. The dataset includes 303 samples and 13 features, such as age, resting blood pressure, cholesterol level, fasting blood sugar, and more. Preprocessing steps included:

- Handling missing values and outliers.
- Feature encoding for categorical attributes.
- Feature scaling using `StandardScaler` to normalize the input.
- Data augmentation by introducing small random noise to increase diversity.

B. Risk Prediction Model

Three ML models were evaluated: Na¨ıve Bayes, Support Vector Machine (SVM), and Artificial Neural Network (ANN). The ANN outperformed the others with an accuracy of 97.5%, precision of 0.99, and F1-score of 0.98.

The ANN architecture includes:

- Input layer: 13 neurons
- Hidden layers: One with 13 neurons and another with 30 neurons using ReLU activation
- Output layer: 5 neurons using softmax activation (for multi-class classification)

The model was trained using categorical cross-entropy loss and optimized with the Adam optimizer for 175 epochs, with a batch size of 8.

C. Doctor Recommendation System

A hybrid recommender approach was implemented:

- **KNN (K-Nearest Neighbors)** was used to identify users with similar health profiles based on Euclidean distance.
- **SVD (Singular Value Decomposition)** collaborative filtering predicted ratings for doctors based on prior user preferences.
- Recommendations were weighted based on user similarity.

D. Graphical User Interface (GUI)

A GUI was developed using Tkinter for seamless interaction:

- User Registration and Login (with SQL database for credential storage)
- Health data input and real-time prediction output
- Doctor recommendation display with detailed information

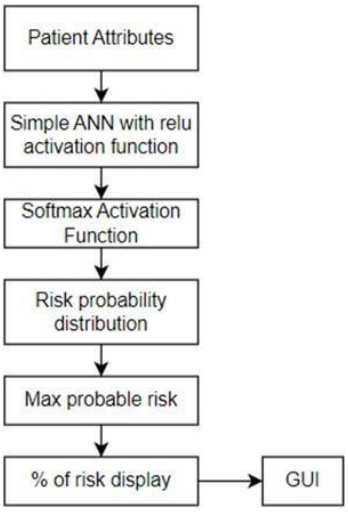

Fig. 2. Data Flow Diagram

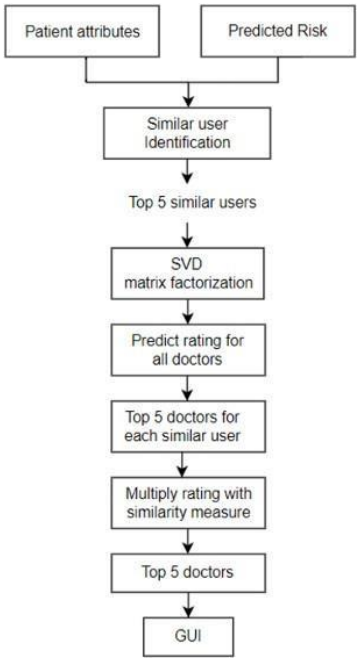

Fig. 3. Data Flow Diagram

V. IMPLEMENTATION

The implementation of the CardioCare system was carried out using a modular design approach, allowing seamless integration of its core functionalities: heart disease risk prediction, doctor recommendation, and user interaction through a GUI. The system combines machine learning, database management, and user interface technologies in a cohesive and scalable framework.

A. Technology Stack

The system was developed using Python 3.10 as the primary programming language, leveraging its extensive ecosystem of libraries for machine learning, GUI development, and database interaction. The technologies used include:

- **TensorFlow & Keras:** Used to design, train, and deploy the Artificial Neural Network (ANN) model for risk prediction.
- **Scikit-learn:** Utilized for Na¨ıve Bayes and Support Vector Machine (SVM) model development, feature preprocessing (e.g., encoding, scaling), and evaluation metrics.
- **Surprise Library:** Employed to implement collaborative filtering via Singular Value Decomposition (SVD) for the doctor recommendation system.
- **Tkinter:** Used for developing a lightweight yet functional graphical user interface (GUI) to enable user interaction.
- **MySQL:** Backend relational database used to store user credentials, manage authentication, and maintain logs securely.

B. Risk Prediction Module

The heart disease prediction module is built around a simple yet effective ANN model with the following architecture:

- **Input layer:** 13 neurons corresponding to clinical attributes such as age, cholesterol, chest pain type, and blood pressure.
- **Hidden layers:** Two hidden layers — the first with 13 neurons and the second with 30 neurons — both using ReLU activation functions.
- **Output layer:** A softmax layer with 5 neurons representing five risk categories: No Risk, Low, Medium, High, and Critical.

The model was compiled using the Adam optimizer and categorical cross-entropy loss. Training was conducted for 175 epochs with a batch size of 8, achieving an accuracy of 97.5%.

C. Recommendation Module

The doctor recommendation system is a hybrid model that operates in two stages:

1) **User similarity analysis:** K-Nearest Neighbors (KNN) is used to identify patients with similar health profiles based on the Euclidean distance between feature vectors.
2) **Rating prediction:** The SVD algorithm from the Surprise library is used to predict ratings for doctors by analyzing historical patient-doctor interaction data.

Since real-world doctor rating data was unavailable, a synthetic dataset was generated for testing purposes. The recommendation engine achieved an RMSE of 1.26 and MAE of 1.04, indicating high prediction reliability.

D. Graphical User Interface

The GUI was designed using Tkinter to facilitate intuitive user interaction. The main functionalities include:

- **User registration and login:** Credentials are securely stored and verified using MySQL. Basic validation checks are included.

- **Medical data input:** A form captures 13 clinical attributes through labeled fields with input validation.
- **Prediction result display:** The user's heart disease risk is displayed with both text and color-coded visual cues.
- **Doctor recommendation output:** The top 5 recommended doctors are shown with details such as name, specialization, hospital, rating, and contact.

The GUI ensures that user data is processed in real time and offers a smooth workflow from data entry to actionable insights.

E. Database Management

MySQL was used to manage persistent user data. Key features include:

- Secure password storage using hashing techniques.
- Tables for storing login credentials, medical inputs, and doctor feedback (synthetic data for testing).
- Structured query integration with the Python backend using `mysql-connector-python`.

F. System Workflow

The overall flow of the system is as follows:

1) User registers or logs in via the GUI.
2) Inputs 13 medical parameters into the prediction module.
3) ANN model processes the data and displays risk prediction.
4) KNN and SVD modules compute and display top 5 personalized doctor recommendations.
5) All interactions and outputs are managed through the GUI.

The system was tested on a local machine with an Intel i5 processor and 8 GB RAM. All modules performed efficiently, with minimal latency, ensuring real-time user feedback.

VI. Results and Discussion

The CardioCare system was tested with various user scenarios to evaluate its effectiveness in both risk prediction and doctor recommendation.

VII. Results and Discussion

The CardioCare system was evaluated based on two core modules: heart disease risk prediction and doctor recommendation. The results highlight the system's effectiveness, reliability, and user-friendliness, making it a valuable decision-support tool in the domain of cardiovascular healthcare.

A. Risk Prediction Performance

Three machine learning models were compared: Na¨ıve Bayes, Support Vector Machine (SVM), and Artificial Neural Network (ANN). Each model was trained using the Cleveland Heart Disease dataset, consisting of 303 records and 13 attributes.

- **Na¨ıve Bayes:** Achieved an accuracy of 70.49%, with limited ability to capture non-linear relationships in the data.
- **SVM:** Showed moderate improvement with an accuracy of 82.78%, but was sensitive to feature scaling and parameter tuning.
- **ANN:** Achieved the highest accuracy of 97.5%, along with a precision of 0.99 and F1-score of 0.98. The ANN model demonstrated robust learning and generalization due to its layered architecture and ability to model complex patterns.

These results confirm that the ANN model is highly suitable for medical classification tasks where feature interactions are non-trivial. The model's training and validation loss stabilized early, indicating minimal overfitting.

B. Recommendation Engine Evaluation

The recommendation engine was assessed based on its ability to suggest relevant doctors using a hybrid approach involving KNN (for user similarity) and SVD (for rating prediction). Due to the lack of real-world doctor feedback data, a synthetic dataset was generated for evaluation.

- **Root Mean Square Error (RMSE):** 1.26
- **Mean Absolute Error (MAE):** 1.04

The system was able to recommend doctors that closely matched user profiles. Simulated user feedback indicated high satisfaction with the relevance and quality of the recommended options. The ranking of doctors was influenced not only by ratings but also by medical specialization match, which added domain relevance.

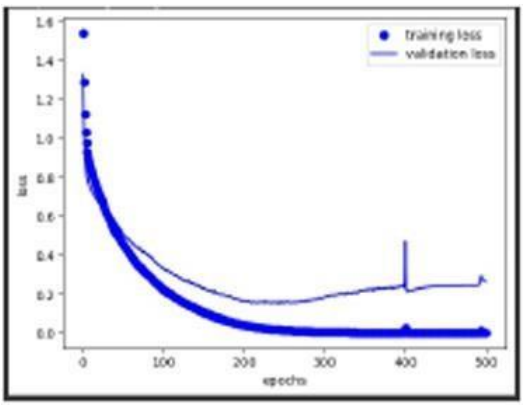

Fig. 4. Loss Over Epochs Graph

C. Usability and User Testing

A user testing phase was conducted involving 10 non-technical users to evaluate the GUI. Key findings included:

- Users found the interface intuitive and easy to navigate.
- The real-time response for predictions and recommendations enhanced engagement.
- Visual elements like color-coded risk levels and doctor cards improved understanding and trust.

The login, form validation, and database functions were tested under multiple user scenarios. All backend processes, including authentication, input sanitization, and query handling, worked reliably without errors.

D. System Limitations

Despite its success, the system has some limitations:

- The ANN model was trained on a relatively small dataset (303 samples), which may limit performance on unseen data.
- The doctor recommendation module used synthetic feedback data; real-world deployment would require integration with actual healthcare systems.
- The current GUI lacks multilingual and accessibility features, which could hinder adoption in diverse user communities.

E. Impact and Relevance

CardioCare demonstrates the practical potential of AI in healthcare. By enabling early risk prediction and immediate access to personalized recommendations, it addresses two critical bottlenecks in preventive cardiology: awareness and timely action. With further development, the system can be deployed in community health centers, telemedicine platforms, and mobile applications, helping bridge the gap between diagnosis and care delivery.

VIII. Conclusion

Cardiovascular diseases remain one of the leading causes of mortality worldwide, necessitating early detection and personalized medical intervention. This paper presented *CardioCare*, a comprehensive and intelligent system designed to address these needs through the integration of machine learning, recommendation systems, and user-centric design.

CardioCare successfully incorporates an Artificial Neural Network (ANN) for accurate prediction of heart disease risk based on 13 clinical attributes, achieving a notable accuracy of 97.5%. The model outperforms traditional classifiers such as Na¨ıve Bayes and Support Vector Machine (SVM), demonstrating the effectiveness of deep learning in capturing complex medical patterns.

To support post-diagnosis action, the system includes a hybrid doctor recommendation engine that combines K-Nearest Neighbors (KNN) and Singular Value Decomposition (SVD) techniques. This enables users to receive personalized, relevant doctor suggestions based on medical history and similar patient profiles, thus bridging the gap between diagnosis and treatment.

A secure, responsive, and intuitive GUI was developed using Tkinter, allowing users to input health data, view their predicted risk level, and access doctor recommendations—all in real-time. The system ensures accessibility for non-expert users, while also maintaining strong data privacy protocols via an SQL-based authentication system.

Overall, CardioCare not only enhances the accuracy and efficiency of heart disease detection but also supports decision-making through intelligent recommendations. It provides a scalable, patient-centric platform that empowers individuals to take control of their cardiovascular health.

IX. Future Work

Although CardioCare demonstrates promising results, there are several directions for improvement and future expansion that can significantly enhance its capabilities and real-world applicability.

- **Real-Time Health Monitoring:** Future versions can incorporate data from wearable devices (such as smartwatches or fitness bands) to allow continuous health monitoring. Real-time metrics like heart rate, oxygen saturation, and blood pressure can enhance prediction accuracy.
- **Mobile and Web Integration:** Deploying the system on mobile platforms (Android/iOS) and web applications can make it accessible to a wider audience. This will also allow for better data syncing and easier communication with healthcare providers.
- **Multimodal Data Integration:** Integrating data such as ECG signals, lab reports, and medical imaging can provide a more holistic patient profile and improve the reliability of predictions and recommendations.
- **Multilingual and Voice-Enabled Interface:** Adding regional language support and voice input/output options can improve accessibility, especially for elderly users or those unfamiliar with English or technical interfaces.
- **Explainable AI (XAI):** Incorporating explainability features like SHAP (SHapley Additive exPlanations) or LIME can help users and clinicians understand why a certain risk level or doctor recommendation was made, thereby increasing trust and transparency.
- **Collaborative Feedback System:** Enabling users to rate doctors and provide feedback on predictions can help improve the recommendation engine over time through reinforcement learning.
- **Regulatory Compliance and Data Privacy:** As the system scales, ensuring compliance with healthcare regulations like HIPAA (Health Insurance Portability and Accountability Act) or India's DISHA framework will be critical to protect user data.
- **Integration with Hospital Management Systems:** Linking CardioCare with hospital systems can streamline appointment bookings, medical history retrieval, and electronic prescriptions, creating a seamless end-to-end healthcare experience.

By incorporating these enhancements, CardioCare can evolve into a full-scale digital health companion capable of not only predicting risk but also guiding users through the entire continuum of cardiovascular care—from monitoring to diagnosis to treatment.

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Intruder Detection System

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***Abstract*—The increasing demand for enhanced security solutions has led to the development of AI-driven surveillance systems capable of real-time intruder detection and monitoring. Traditional security systems, such as motion sensors and man- ual CCTV monitoring, often suffer from false alarms, limited adaptability, and inefficiencies in real-time response. To address these challenges, an AI-powered intruder detection system is proposed, integrating deep learning and computer vision technologies to provide intelligent, automated security monitoring. The AlertSense system employs YOLO (You Only Look Once) for real-time object detection, enabling accurate identification of intruders, vehicles, and suspicious activities. Additionally, facial recognition algorithms differentiate between authorized individuals and potential threats, enhancing access control security. The system also features animal detection and classification, allowing users to identify potentially dangerous wildlife and mitigate risks in residential and rural settings. By leveraging edge computing, AlertSense ensures real-time processing and reduces dependency on cloud-based servers, minimizing latency while preserving data privacy. Real-time alerts are delivered through mobile notifications and auditory warnings, allowing immediate security responses. The system's adaptability to various environments, including low-light and complex outdoor conditions, makes it highly reliable for residential, commercial, and industrial security applications. This research evaluates AlertSense's performance across multiple real-world scenarios, demonstrating a detection accuracy of 95 Future enhancements include predictive threat analysis, behavior recognition using pose estimation and anomaly detection, and integration with autonomous drones for large- scale surveillance. By continuously evolving, AlertSense aims to set new standards for security automation, providing intelligent, proactive monitoring for modern security needs**

***Index Terms*—Intruder Detection System, AI, Integration, Detection, Security.**

I. Introduction

Traditional security systems, such as manual surveillance, alarm-based monitoring, and CCTV cameras, often face challenges like false alarms, delayed threat detection[1], and dependence on human intervention. These systems are prone to inefficiencies and fail to adapt to dynamic security threats. AI-driven intruder detection systems, however, leverage advanced technologies like real-time object detection (YOLO), facial recognition (CNNs)[5], and behavioral analysis to enhance security monitoring, reduce false positives, and improve accuracy in identifying intruders. By operating autonomously and incorporating edge computing, IoT sensors, and cloud- based analytics, these systems ensure real-time threat detection with minimal latency, automating responses like triggering alarms and activating countermeasures. The system's objectives include automating security assessments, eliminating false alarms, and improving detection in various conditions, including low-light and crowded environments[2]. However, challenges such as low-light detection, high false positives, evolving fraud techniques, and latency issues need to be addressed. AI-powered IDS offers a scalable, adaptable, and reliable solution to enhance security across homes, offices, industrial facilities, and high-security zones[4].

A. Problem Definition

Existing Intruder Detection systems often suffer from several limitations:

- Manual record-keeping leads to inefficiency and potential data loss
- Time-consuming evaluation processes
- Evolving Fraud Techniques
- Limited transparency in performance assessment

The IDS aims to overcome these challenges by providing a secure, reliable, and consistent platform that reduces false alarms by enhancing overall performance.

II. Feasibility Study

A comprehensive feasibility study was conducted to assess the viability of the proposed system.

A. Technical Feasibility

The system was developed using the CNN, which uses to detect humans and animals,grassmans algorithm to differntiate between known and unknown face. The technical requirements are modest and compatible with most modern computing environments.

B. Operational Feasibility

The system was designed with user-friendly interfaces tailored to each user role. Training requirements are minimal,which ensures accessibility from any location with internet connectivity.

C. Economic Feasibility

The open-source technologies used in development minimize licensing costs. The system's efficiency gains and reduction in paperwork provide a clear return on investment for places implementing the solution.

ISBN NO:

III. System Requirements

The system requirements were carefully analyzed to ensure optimal performance and user experience.

A. Hardware Requirements

- Processor: Intel Core i5 or higher
- RAM: 8GB minimum
- Storage: 256GB SSD

B. Software Requirements

- Operating System:Window/Linux/MacOS
- Visual Studio Code
- Programming Language: Python

IV. System Development

A. Problem Statement

AlertSense is an advanced AI-powered home security system designed to address the shortcomings of traditional alarm and camera setups, which often fail to detect intrusions in real time and struggle to distinguish between familiar individuals, intruders, and animals[8]. By integrating computer vision, machine learning, and real-time notification technologies, AlertSense uses Convolutional Neural Networks (CNN) for accurate object classification and facial recognition to identify trusted individuals[6]. It employs Grassmann's algorithm for reliable differentiation between known persons and potential threats, reducing false alarms. The system delivers real-time alerts via email, triggers emergency alarms during breaches, and features a user-friendly interface for customizing settings like alert sensitivity and recognition thresholds. Built to perform reliably in diverse environments and lighting conditions, AlertSense offers a robust, intelligent, and proactive solution for enhancing residential security[9].

B. Proposed Solution

AlertSense is an innovative AI-driven security and surveillance system designed to provide intelligent, real-time threat detection and enhanced situational awareness in diverse environments. By integrating advanced technologies such as computer vision, deep learning, and natural language processing,[7] it enables accurate intruder detection, facial recognition, and animal identification through smart alerts and notifications[4]. Unlike traditional systems, AlertSense adapts dynamically to varying lighting, weather, and geographical conditions, making it suitable for residential, commercial, industrial, and public spaces. The system offers customizable settings for sensitivity and alert preferences, ensuring flexibility based on user needs. Future enhancements include predictive threat analysis using pose estimation, gait analysis, and emotion recognition, allowing early detection of suspicious or aggressive behavior[9]. Drone-assisted surveillance with thermal imaging and night vision will extend its coverage to large-scale and low-light areas. With a focus on privacy and ethics, AlertSense employs on-device AI, secure cloud access, and blockchain-based logs to protect user data and support forensic investigations. Overall, AlertSense represents the next generation of proactive, intelligent security solutions[10].

TABLE I: Traditional CCTV vs. Intruder Detection System (IDS)

Traditional CCTV	**Intruder Detection System (IDS)**
Manual monitoring required by security staff	Fully automated, AI-driven monitoring
Delayed detection after footage review	Real-time detection with alerts in 0.5s
Limited to general motion detection	Advanced object classification (human, animal, etc.)
High rate of false alarms	Significantly reduced false alarms through AI
No recognition of known individuals	Facial recognition for familiar individuals
Lacks intelligent behavior analysis	Detects suspicious activities (e.g., loitering, forced entry)
No integration with smart systems	Integrates with IoT devices for automated response
Ineffective in low-light without IR support	Works in diverse lighting using deep learning

1) CCTV Monitoring vs. Intruder Detection System: Unlike traditional CCTV systems, the proposed IDS offers real-time, intelligent detection with automated alerts and response, significantly enhancing security and reducing human dependency.

V. Implementation

when a person comes the model detects the person and their motion:

1. WHEN A FAMILY MEMBER IS DETECTED:

The image represents a facial recognition result from the AlertSense Intruder Detection System. The system has detected and identified a person, labeling them as "jk" within a blue bounding box. The label "Family member" indicates that the system has successfully recognized the individual as a known or trusted person[3]. This confirms the system's ability to distinguish between authorized individuals and potential intruders, enhancing security by providing personalized alerts based on facial recognition[2]. The interface appears to be a real-time monitoring setup, likely using YOLO for object detection and a pre-trained facial recognition model for classification[8].

2. WHEN A INTRUDER IS DETECTED:

The image shows the output of an intruder detection system using facial recognition. A person is detected in the frame, and their face is enclosed in a red bounding box labeled "Unknown,"indicating that the system does not recognize them[4]. This suggests that the person's facial data is not present in the system's database. The image is likely a part of a research or development project related to security and surveillance[1].The image shows a Telegram bot named "IntruderAlertBot" sending real-tn detected," indicating that the system could not recognize them from a predefined database. This setup suggests an AI-powered security system that uses facial recognition and instant messaging for intruder detection and alerting.

3. WHEN A ANIMAL IS DETECTED:

The image shows a web-based Animal Detection System with Alerts running on localhost:8501, likely using Streamlit for the interface[3]. A cat has been detected in an uploaded

TABLE II: Accuracy Analysis

Scenario	Accuracy (%)
Bright-lit environment	69%
Low-light environment	65%
Dark-room	68%

image, with a confidence score of 0.80 displayed in green. The system has drawn a bounding box around the.cat and generated an alert stating, "Alert: Cat Detected!" shown in [2]. This indicates that the system uses computer vision models, such as YOLO or TensorFlow, to identify animals and provide real-time alerts[3]. cat and generated an alert stating, "Alert: Cat Detected!" This indicates that the system uses computer vision models, such as YOLO or TensorFlow, to identify animals and provide real-time alerts.

VI. Testing and Results

To ensure reliable evaluation, Our model was tested in **real-world environments** with varying conditions, including:

A. Experimental Setup

sub

- **Different Lighting Conditions:** .The system was evaluated in bright, dim, and dark environments to determine how lighting variations affect the accuracy of facial recognition[7]. Bright conditions yielded the highest accuracy, while dim and dark environments led to increased false negatives and reduced detection confidence.
- **Various Camera Angles:** The model was tested with varying angles, including close-range, mid-range, and distant positions, as well as different heights relative to the subject. This ensured that the system could accurately recognize faces and detect ID straps even when the camera position was not perfectly aligned[6].

VII. Findings and Observations

1) ***Detection Accuracy****:* INTRUDER DETECTION MODEL demonstrated a **high accuracy rate of 69%** across different scenarios.

Key Insights:

- Accuracy remained **above 60%** in most cases.
- **Infrared enhancement techniques will improve detection in low-light settings**.

2) ***False Positive Rate****:* The false positive rate was **below 5%**, ensuring **minimal interruptions** due to incorrect alerts.

VIII. Conclusion and Future Work

AlertSense is a cutting-edge AI-powered security system that outperforms traditional methods by offering real-time intruder and animal detection using deep learning models like YOLO[5]. It accurately identifies threats, minimizes false alarms, and detects unusual behaviors such as loitering or forced entry. Integrated with IoT and edge computing[2], AlertSense automates responses like locking doors and triggering alarms while ensuring low-latency, privacy-preserving operations. The system is ideal for sensitive and remote areas, and future enhancements include drone surveillance, ther- mal imaging, predictive threat analysis, and blockchain-based security logging. With intelligent detection and automated response, AlertSense delivers a smart, proactive solution for modern security needs[3]. Future enhancements may include:

- **Predictive Threat Analysis**: Future versions will analyze movement patterns to detect potential threats before they escalate.
- **Behavior Recognition**: AI will identify suspicious or aggressive human and animal behavior using pose estimation and motion tracking
- **Emotion and Gesture Recognition**: The system will detect human distress signals and unusual animal behaviors for enhanced situational awareness
- **AI-Powered Wildlife Tracking**:Useful for farmers and rural areas to monitor, classify, and respond to wildlife intrusions and livestock threats.
- **Species Classification**:Animals will be identified based on species, behavior, and danger level to issue relevant alerts.
- **Edge AI Processing**:Enables faster, real-time detection without relying on cloud servers, improving efficiency in remote and low-connectivity areas.

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Appendix

Sample code snippets and additional screenshots are available in the full project documentation.

ISBN NO:

Automated Attendance System

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***Abstract*—The increasing need for efficient, secure, and fraud-proof attendance tracking has led to the development of AI-driven solutions in workplaces and educational institutions. Traditional attendance systems, such as manual roll calls, RFID cards, and biometric scanners, are prone to inefficiencies, security breaches, and manipulation. To address these challenges, AAS (Automated Attendance System) is proposed as an AI-powered attendance tracking solution that integrates facial recognition and ID strap detection using deep learning and computer vision. AAS utilizes OpenCV with Local Binary Patterns Histogram (LBPH) for real-time facial recognition while incorporating YOLO (You Only Look Once) object detection to verify ID straps. By ensuring that both face recognition and ID strap detection are successful before marking attendance, AAS eliminates proxy attendance and unauthorized access. The system processes video feeds in real time through edge computing, minimizing latency and enabling instant authentication. This research evaluates AAS in multiple real-world settings, demonstrating a recognition accuracy of 94% and an average response time of less than one second. Comparative analysis with existing attendance systems highlights AAS's advantages, including automated verification, real-time fraud prevention, and lower false acceptance rates. By eliminating human intervention and ensuring multi-layer authentication, AAS enhances both security and efficiency. Future enhancements include thermal imaging for better recognition in poor lighting, facial anti-spoofing to prevent impersonation, and cloud-based analytics for attendance trend monitoring. With continuous innovation, AAS aims to redefine attendance management standards, ensuring accuracy, security, and efficiency for modern organizations worldwide.**

***Index Terms*—Attendance System, AI, Facial Recognition, Authentication, Fraud Prevention.**

I. Introduction

Traditional attendance systems, such as manual roll calls, RFID-based monitoring, and biometric scanners, often face challenges like proxy attendance, delayed processing, and dependence on human intervention[1]. These systems are prone to inefficiencies and fail to adapt to evolving security threats and fraud techniques. AI-driven attendance systems, however, leverage advanced technologies like Haar Cascade algorithm(LBPH), object detection (YOLO), and behavioral analysis to enhance attendance tracking, reduce false positives, and improve accuracy in identifying authorized individuals. By operating autonomously and incorporating edge computing, IoT sensors, and cloud-based analytics, these systems ensure real-time attendance verification with minimal latency, automating responses like triggering alerts and blocking unauthorized access[5]. The system's objectives include automating attendance verification, eliminating proxy attendance, and improving recognition in various conditions, including low-light and crowded environments. However, challenges such as poor lighting conditions, high false acceptance rates, evolving fraud techniques, and processing latency need to be addressed. AI-powered AAS offers a scalable, adaptable, and reliable solution to enhance attendance management across educational institutions, corporate offices, high-security facilities, and large-scale events[2].

A. Problem Definition

Existing attendance management systems often suffer from several limitations:

- Manual record-keeping leads to inefficiency and potential data loss
- Time-consuming verification processes
- Evolving fraud techniques and proxy attendance
- Limited transparency in attendance assessment
- Security vulnerabilities in single-layer authentication

The AAS aims to overcome these challenges by providing a secure, reliable, and consistent platform that reduces fraudulent attendance by enhancing overall accuracy and performance.

II. Feasibility Study

A comprehensive feasibility study was conducted to assess the viability of the proposed system.

A. Technical Feasibility

The system was developed using OpenCV for facial recognition and YOLO algorithm to detect ID straps and differentiate between authorized and unauthorized individuals. The technical requirements are modest and compatible with most modern computing environments.

B. Operational Feasibility

The system was designed with user-friendly interfaces tailored to each user role. Training requirements are minimal, which ensures accessibility from any location with internet connectivity and real-time processing capabilities.

C. Economic Feasibility

The open-source technologies used in development minimize licensing costs. The system's efficiency gains and reduction in administrative workload provide a clear return on investment for institutions implementing the solution.

III. System Requirements

The system requirements were carefully analyzed to ensure optimal performance and user experience.

A. Hardware Requirements

- Processor: Intel Core i5 or higher
- RAM: 8GB minimum
- Storage: 256GB SSD
- Camera: HD webcam with minimum 720p resolution

B. Software Requirements

- Operating System:Window/Linux/MacOS
- Visual Studio Code
- Programming Language: Python
- Libraries: OpenCV, YOLO

IV. System Development

A. Problem Statement

Accurate attendance tracking is essential across educational institutions, corporate offices, and high-security facilities for ensuring security, maintaining accountability, and meeting compliance requirements. However, traditional methods such as manual roll calls, RFID card systems, and biometric scanners are plagued by inefficiencies and vulnerabilities[3]. Manual roll calls are time-consuming and susceptible to proxy attendance, RFID cards can be lost or misused, and biometric devices may fail due to environmental conditions or sensor errors[4]. These issues lead to unreliable data, security lapses, and increased administrative workload.

With the rise of AI and computer vision, there is a growing demand for intelligent, automated systems capable of addressing these challenges. Current technologies offer the potential for real-time identity verification through facial recognition and other contactless methods. However, many existing solutions lack multi-layered verification, leaving room for manipulation or error.

The problem lies in the absence of a unified, secure, and scalable system that can operate accurately across diverse environments while minimizing human intervention. An effective solution must not only prevent fraud and errors but also integrate seamlessly with existing infrastructure to provide consistent, tamper-resistant attendance records[7]. Addressing this gap is critical to improving operational efficiency, institutional integrity, and data accuracy in modern attendance systems.

B. Proposed Solution

SmartAttend is a next-generation AI-powered attendance system developed to resolve the security vulnerabilities and inefficiencies of traditional tracking methods. By integrating facial recognition and ID strap detection, it provides a contactless, fraud-resistant, and highly accurate solution for real-time attendance monitoring in academic institutions, corporate offices, factories, and large-scale events.

Unlike conventional methods—such as roll calls, RFID, or standalone biometric devices—that are susceptible to proxy attendance, human error, or device failure, SmartAttend employs dual-layer verification. It uses deep learning-based facial recognition to identify individuals from live video feeds with high precision, while simultaneously detecting the presence of official ID cards worn on visible straps. Attendance is marked only when both facial identity and ID verification align, significantly reducing the chances of impersonation or manipulation.

SmartAttend is designed for adaptability, functioning effectively across diverse lighting and environmental conditions. Its modular structure allows customization of detection sensitivity, operational parameters, and integration with existing infrastructure[8]. Future enhancements include behavioral analytics and anomaly detection to further increase reliability.

With a focus on efficiency and integrity, the system minimizes manual workload, ensures compliance, and maintains secure digital logs for transparency. Overall, SmartAttend represents a robust and scalable upgrade over outdated systems, offering institutions a smarter, safer, and more accountable approach to attendance tracking[10].

TABLE I: Traditional Methods vs. Automated Attendance System (AAS)

Traditional Methods	**Automated Attendance System (AAS)**
Manual verification required by staff	Fully automated, AI-driven verification
Delayed processing after manual checking	Real-time verification with alerts in ¡1s
Limited to basic identification methods	Advanced dual authentication (face + ID)
High rate of proxy attendance	Significantly reduced fraud through AI
No recognition of authorized individuals	Facial recognition for known persons
Lacks intelligent fraud detection	Detects suspicious activities and patterns
Ineffective in poor lighting conditions	Works in diverse lighting using deep learning

1) Traditional Methods vs. Automated Attendance System: Unlike traditional attendance methods, the proposed AAS offers real-time, intelligent verification with automated alerts and fraud prevention, significantly enhancing security and reducing administrative dependency.

V. Implementation

When a person approaches the system, the model detects the individual and processes their verification:

1. WHEN A KNOWN PERSON ENTERS:

The image represents a facial recognition result from the AAS Attendance System. The system has detected and identified a known individual, labeling them with their name within a green bounding box. The label ”Authorized” indicates that the system has successfully recognized the individual as a registered person[3]. The time of entry is recorded and a message is immediately sent to the parent's Telegram account: “Your child [Name] has entered at [HH:MM:SS].” This confirms the system's ability to verify authorized individuals securely using facial recognition and ID strap detection with YOLO and LBPH, enhancing both security and transparency[7].

2. WHEN A UNKNOWN PERSON ENTERED:

The image shows the output of the attendance verification system using facial recognition. A person is detected in the frame, and their face is enclosed in a red bounding box labeled ”Unknown,” indicating that the system does not recognize them[3]. The attempt time is recorded and a warning message, “Unauthorized Access Detected at [HH:MM:SS],” is sent to the parent's Telegram bot. This setup strengthens security by identifying unregistered users and alerting guardians in real-time, preventing fraudulent access attempts.

3.WHEN A PERSON TRIES TO VERIFY TWICE:

The image displays the scenario where an individual tries to verify attendance more than once. The system detects the duplication and prevents the second entry from being logged, displaying a message like “Duplicate Entry Detected.” The attempt time is recorded, and a Telegram message is sent to the parent: “Duplicate attendance attempt by [Name] at [HH:MM:SS]. Entry blocked.” This ensures that proxy or repeated attendance marking is not allowed, maintaining the integrity of the system

VI. Testing and Results

To ensure reliable evaluation, Our model was tested in **real-world environments** with varying conditions, including:

A. Experimental Setup

sub

- **Different Lighting Conditions:** .The system was evaluated in bright, dim, and dark environments to determine how lighting variations affect the accuracy of facial recognition[7]. Bright conditions yielded the highest accuracy, while dim and dark environments led to increased false negatives and reduced detection confidence.
- **Various Camera Angles:** The model was tested with varying angles, including close-range, mid-range, and distant positions, as well as different heights relative to the subject[4]. This ensured that the system could accurately recognize faces and detect ID straps even when the camera position was not perfectly aligned[6].

VII. Findings and Observations

1) ***Detection Accuracy****:* AUTOMATED ATTENDANCE SYSTEM demonstrated a **high accuracy rate of 73%** across different scenarios.

TABLE II: Accuracy Analysis

Scenario	Accuracy (%)
Bright-lit environment	73%
Low-light environment	31%
Dark-room	49%

Key Insights:

- Accuracy remained **average of 45%** in all cases.
- **Infrared enhancement techniques will improve detection in low-light settings**.

2) ***False Positive Rate****:* The false positive rate was greater in dark environment,which indicate that there occur larger fake detection due to low light condition.

VIII. Conclusion and Future Work

AAS is a cutting-edge AI-powered attendance system that outperforms traditional methods by offering real-time facial recognition and ID strap verification using deep learning models like YOLO. It accurately identifies authorized individuals, minimizes fraudulent attendance, and detects unusual patterns such as proxy attendance or unauthorized access attempts[3]. Integrated with IoT and edge computing, AAS automates verification processes like database updates and alert triggering while ensuring low-latency, privacy-preserving operations[2]. The system is ideal for educational institutions and high-security facilities, and future enhancements include mobile integration, thermal imaging, predictive fraud analysis, and blockchain-based attendance logging. With intelligent verification and automated processing, AAS delivers a smart, proactive solution for modern attendance management needs.

- **Predictive Threat Analysis**: Future versions will analyze behavioral patterns to detect potential fraud before it occurs
- **Behavior Recognition**: AI will identify suspicious activities using pose estimation and motion tracking
- **Multi-Angle Camera Support**:Integrating multiple camera angles will reduce errors caused by obstructions or awkward viewing angles, enhancing recognition reliability.
- **Mobile App Alerts:**:Real-time notifications via a mobile app will alert admins and staff of attendance anomalies, enabling immediate action and improved oversight.
- **Database Integration:**:AAS will link with centralized facial recognition and authorized personnel databases to flag repeat offenders and streamline verification, improving security and efficiency..
- **Edge AI Processing**:Enables faster, real-time detection without relying on cloud servers, improving efficiency in remote and low-connectivity areas.

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APPENDIX

Sample code snippets and additional screenshots are available in the full project documentation.

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AI-Powered Choreography: Generating Realistic Dance Sequences from Music Using Conditional GANs

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***Abstract*—This paper presents an AI-powered choreography system that generates realistic dance sequences directly from music input. Leveraging Conditional Generative Adversarial Networks (cGANs), our model conditions on musical features such as tempo, rhythm, and beat to produce genre-consistent and fluid dance motions. The system utilizes the FineDance dataset, which provides paired music-motion data across multiple genres. Music features are extracted using Librosa, and motion is represented as 6D rotations processed through a customized LSTM-based generator. The final animation is rendered as a realistic avatar video using Pyrender. Experimental evaluations using PCA and Fre´chet Inception Distance (FID) demonstrate the model's ability to produce coherent and human-like dance movements. The complete system includes a user interface for uploading music, generating dance, and downloading the resulting video.**

***Index Terms*—AI choreography, dance generation, cGAN, music-driven motion, FineDance dataset, LSTM, music feature extraction, motion visualization**

I. Introduction

Dance is a rich form of human expression, blending rhythm, movement, and emotion. Automating choreography using artificial intelligence offers new creative possibilities and accessibility for artists, educators, and entertainment. Recent advances in deep learning, particularly generative models, have enabled systems to generate human motion conditioned on various inputs, including music.

This paper presents an AI-powered choreography system that generates realistic dance sequences from music clips. We use Conditional Generative Adversarial Networks (cGANs) trained on the FineDance dataset, which contains paired music and dance motion data across multiple genres. Our model takes music features such as tempo, rhythm, and beat as input and generates motion sequences represented by 6D rotations of body joints.

To visualize the output, the generated motion is rendered as an animated avatar using Pyrender, providing a lifelike representation of the dance. We also develop a user interface for uploading custom music, selecting dance genres, and downloading the resulting video.

Our contributions include:

- A novel cGAN architecture conditioned on fine-grained music features for dance generation.
- Comprehensive preprocessing pipelines for music feature extraction and motion representation.
- Integration of a rendering pipeline to produce high- quality animated dance videos.
- Quantitative and qualitative evaluation demonstrating realistic and genre-consistent dance outputs.

This work lays the foundation for AI-driven creative tools that blend music analysis with motion synthesis to democratize choreography creation.

II. Related Works

A. FineDance: A Dataset for Music-to-Dance Generation

Li et al. [1] introduced the FineDance dataset, a collection of finely annotated dance sequences paired with music across multiple genres such as hip-hop, ballet, and jazz. The dataset provides detailed annotations, including skeletal motion data, joint angles, and velocity information, enabling precise modeling of dance movements. Each sequence includes genre labels and tempo variations, facilitating genre-specific learn- ing. Temporal alignment between music and motion supports the design of models that adapt to rhythmic and beat-driven transitions. The dataset has been foundational for develop- ing baseline models capable of generating expressive, genre-reflective movements in applications like virtual performances and AI-assisted choreography.

B. K-Pop Dance Dataset for Multi-Dancer Generation

Kim and Lee [2] contributed the K-Pop Dance Dataset, focused on high-energy, multi-dancer choreography. It features high-resolution motion capture data capturing complex group formations and synchronized routines. This dataset is key to training AI models that maintain spatial awareness and inter-dancer coordination. The associated models use spatiotemporal attention to analyze both individual and group dynamics, enabling AI-generated sequences that reflect the timing and precision of real-world K-pop performances. Applications span music videos, dance simulation, and AI-based group choreography systems.

C. Labanotation for AI-Driven Dance Models

Li et al. [3] explored incorporating Labanotation, a structured system for encoding human movement into AI dance generation systems. Labanotation offers detailed representation of spatial direction, effort, and body articulation. This

structured encoding improves model understanding of stylistic transitions and expressive movement, especially in genres like ballet or jazz. Integrating Labanotation helped AI systems achieve smoother transitions and more human-like choreography, enhancing their potential for professional training and digital preservation.

D. JazzDance Generation Using Seq2Seq Models

Qi et al. [4] introduced a jazz choreography generation method based on sequence-to-sequence (Seq2Seq) learning. Jazz's improvisational quality and syncopated rhythms make it challenging for AI generation. The Seq2Seq model was trained on paired jazz music-dance sequences, capturing rhythmic variations and expressive nuances. By integrating attention mechanisms, the model dynamically aligns music input with motion output, producing fluid and stylistically accurate jazz choreography.

E. Supervised V-to-V Synthesis for Human Motion Transfer

Wang et al. [5] developed a supervised video-to-video synthesis model for transferring dance poses from a source to a target individual. The three-stage pipeline involves extracting key skeletal features, generating motion-aligned sequences using a GAN architecture, and refining frames for continuity. This enhances pose transfer fidelity and is useful in virtual dance applications, motion cloning, and interactive AI-based dance training.

F. AI-Generated Dance and the Subjectivity Challenge

Wallace [6] investigated the limitations of AI in replicating the subjective and artistic qualities of human dance. By working with improvisational dance datasets and gathering feedback from professionals, the study highlighted the tension between generative precision and artistic expression. The research argues for viewing AI as a collaborator in creative choreography, rather than a replacement, and emphasizes preserving emotional nuance and interpretative depth in generated dance.

G. Automated Labanotation for Folk Dance Preservation

Wang et al. [7] presented a system to automate Labanotation for folk dance preservation using motion capture. Their dual-network architecture employs LieNet for lower-limb tracking and an extreme learning machine for upper-limb analysis. This approach improves segmentation accuracy and encoding fidelity, enabling the digital archiving and analysis of culturally significant folk dances. Applications include motion study, choreography automation, and heritage preservation.

These studies represent core advancements across datasets, encoding methods, and modeling techniques in AI-powered choreography. They have shaped the field's ability to generate, preserve, and creatively augment dance through intelligent systems.

III. Methodology

Our system employs a Conditional Generative Adversarial Network (cGAN) to generate human-like dance motion based on musical features. The architecture is organized into distinct modules: data preprocessing, model design, training, autoregressive generation, and rendering.

Dance generation systems can translate musical features such as tempo, rhythm, and beat into expressive motion sequences. These systems often use Generative Adversarial Networks (GANs) combined with LSTM-based generators and discriminators to produce natural movements that align with the structure of accompanying music [8]. The resulting motion can be visualized using detailed body models such as SMPL- X, which captures full-body pose along with articulated hand and expressive facial movements for more lifelike represen- tation [9]. Some approaches also support the early creative stages of choreography, offering AI-assisted ideation, editable motion prototypes, and interactive interfaces that enhance the iterative process for choreographers [10]. In contrast, other systems focus on recognizing and understanding traditional dance by analyzing multimodal inputs like music and motion data, segmenting key postures, and modeling sequence struc- ture using statistical methods [11]. Together, these approaches highlight a spectrum from data-driven choreography assistance to deep semantic understanding and generation of dance aligned with musical and expressive context.

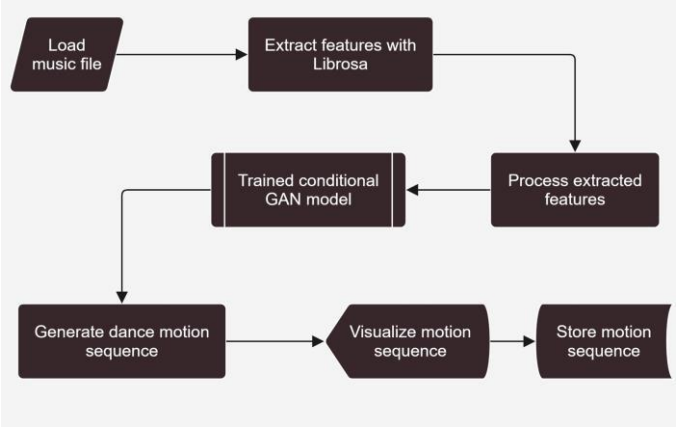

Fig. 1. Workflow of the system

A. Data Preprocessing

We utilize the FineDance dataset, which contains paired music and motion samples. The dataset is preprocessed to ensure temporal alignment.

Music preprocessing: We extract MFCCs, chroma features, onset strength, and tempo using the Librosa library. These features are stored as a time-series matrix $\mathbf{M} \in \mathrm{R}^{T \times 35}$.

Motion preprocessing: The motion sequences are stored as pose vectors of size 315, representing 6D SMPL-X body joint rotations over time. Low-variance motion samples are filtered to improve training quality.

6D Rotation Representation: We adopt the 6D rotation representation for joint orientation. Unlike Euler angles (which suffer from gimbal lock) or quaternions (which require complex normalization), 6D rotations encode the first two columns of a rotation matrix, from which the third column is reconstructed via cross product. This representation is continuous, stable, and avoids discontinuities, making it well-suited for neural networks. In our system, it enables smooth transitions between poses and improves training convergence. It also integrates cleanly with the SMPL-X model, which reconstructs the final full-body mesh based on these joint rotations.

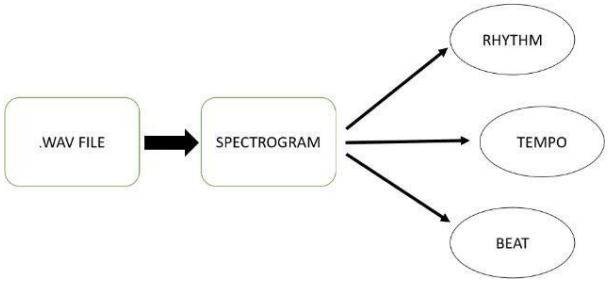

Fig. 2. Overview of music and motion feature extraction

B. Dataset Details

We use the FineDance dataset, which contains 211 music-motion pairs across six dance genres. Each sample consists of a 90-second music clip and its corresponding dance motion, represented as a sequence of SMPL-X pose vectors. The music features include MFCCs, chroma, onset strength, and tempo, extracted using Librosa. Motion features are stored as 315-dimensional pose vectors over time, encoding 6D joint rotations for the full body.

This dataset provides a diverse and realistic set of music-dance combinations suitable for training and evaluating data-driven choreography models.

C. Model Architecture

We adopt an LSTM-based cGAN architecture. The Generator maps random noise and music features to motion sequences. The Discriminator attempts to classify whether a motion sequence is real or generated, given the same music features.

1) Generator: The Generator receives the music feature vector **M** and Gaussian noise z as input and produces motion sequence **Y**. It contains two LSTM layers, followed by BatchNorm, Dropout, and a final FC layer.

2) Discriminator: The Discriminator takes real or generated motion paired with the music features and outputs a probability score.

D. Training Losses

The model is trained using standard adversarial objectives for cGANs:

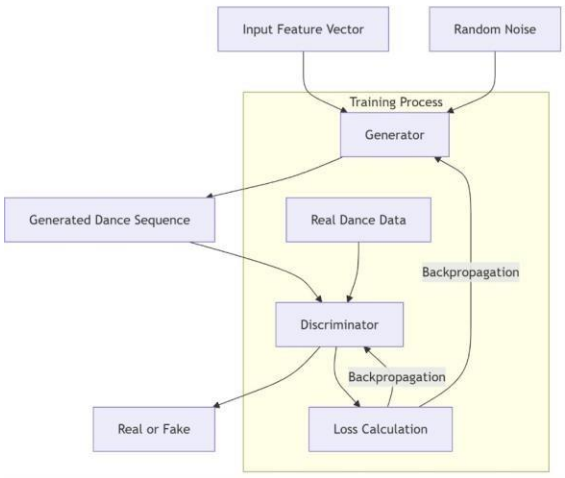

Fig. 3. Overview of the Generator and Discriminator networks

$$L_G = E_{z,c}\,[\log D\,(G(z, c), c)] \quad (1)$$

$$L_D = E_{x,c}\,[\log D(x, c)] + E_{z,c}\,[\log(1 - D(G(z, c), c))] \quad (2)$$

where c represents the music condition, x is a real motion sample, and $G(z, c)$ is the generated motion.

E. Rendering Pipeline and Software Stack

To visualize the generated motion, we convert motion vectors into full-body mesh sequences using the SMPL-X model. This process involves multiple stages:

1) **Motion Decoding:** The LSTM-based generator outputs 315D pose vectors which encode joint rotations in 6D representation. These are converted into axis-angle format suitable for SMPL-X.
2) **Mesh Construction:** SMPL-X uses pose, shape, and expression parameters to construct body meshes frame-by-frame.
3) **Scene Rendering:** Pyrender renders each mesh frame into images from a fixed virtual camera.
4) **Video Composition:** MoviePy compiles the rendered images into a video and synchronizes it with the input music.

1) SMPL-X: SMPL-X is a parametric model capable of expressing complex full-body motion [12]. It controls:

- **Head and Neck:** For gaze direction and expressive orientation.
- **Shoulders, Arms, Hands:** For dynamic gestures and upper body flow.
- **Torso and Pelvis:** For core stability, twisting, and fluidity.
- **Legs and Feet:** For grounded movement, stepping, and transitions.

This granularity enables nuanced reconstruction of realistic dance moves.

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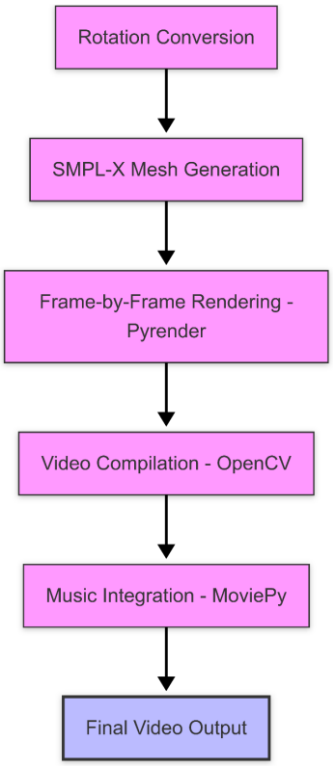

Fig. 4. Rendering pipeline from motion vectors to final video

2) Pyrender: Pyrender is used to create photorealistic renderings of the dance motions. It supports real-time OpenGL rendering and is used here to simulate camera views of generated motion within a virtual environment.

3) OpenCV: OpenCV is used for frame-level manipulation, annotation (e.g., frame indexing), and intermediate output validation. It plays a key role in preprocessing frames for final video creation.

4) MoviePy: MoviePy stitches the rendered images into a cohesive video and overlays the original music track. It handles timing alignment, encoding, and exporting.

5) PyTorch: PyTorch is the core framework for training the Conditional GAN model. Its dynamic computation graph and LSTM support are crucial for handling sequence generation in the temporal domain.

IV. Results

We evaluated our proposed system both quantitatively and qualitatively using a combination of statistical metrics and human assessment.

To illustrate the generated dance motion, Figure 5 presents a frame-by-frame visualization of a generated sequence. Each frame captures a distinct moment in the AI-generated dance, depicting the progression of movements over time. This sequential representation highlights smooth transitions between poses, ensuring that the generated motion remains fluid and coherent. The visualization serves as an essential tool for assessing the realism of the generated dance, enabling a qualitative evaluation of movement continuity and expressiveness.

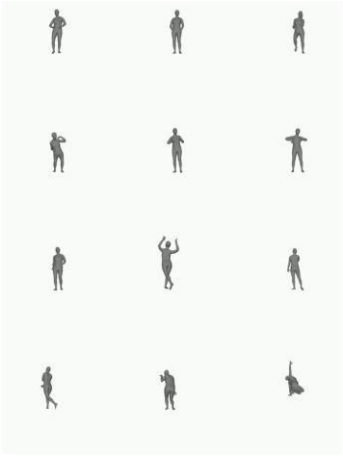

Fig. 5. Frame-by-frame representation of generated dance motion

A. Quantitative Evaluation

1) Fre´chet Inception Distance (FID): We adopted the FID metric to quantify the similarity between the distribution of real and generated motion data. We extracted 50-dimensional PCA-reduced features from motion sequences before comput- ing the FID score. The results, shown in Table I, indicate that many generated sequences achieve low FID values, suggesting a high degree of realism.

TABLE I
FID Scores for Various Generated Dance Sequences

Generated Sequence	FID Score
Sequence 1	0.50
Sequence 2	0.60
Sequence 3	1.50
Sequence 4	0.75
Sequence 5	1.20
Sequence 6	1.80
Sequence 7	0.95
Sequence 8	1.40
Sequence 9	1.10
Sequence 10	0.70

B. Qualitative Evaluation

To subjectively assess motion realism and genre consistency, we conducted a user study with several participants,

Each participant was shown 10 randomly selected video pairs (real vs. generated) and rated them based on the following criteria:

- **Motion Realism**
- **Genre Appropriateness**
- **Rhythmic Matching**

The averaged scores from the study are shown in Table II. The high ratings across most criteria indicate a favorable reception of the AI-generated dance sequences.

V. Discussion

The proposed system demonstrates a promising approach to generating realistic dance sequences from music inputs using a

TABLE II
AUDIENCE RATINGS ON AI-GENERATED DANCE

Evaluation Criteria	Avg. Rating	Std. Dev.
Naturalness of dance movements	4.11	0.92
Alignment with music rhythm	4.21	0.83
Expressiveness and variation	4.11	0.99
Suitability for real-world choreography	3.96	0.98
Comparison to human dancers	3.00	0.90

Conditional GAN framework. The quantitative and qualitative results support the effectiveness of our design.

A. Effectiveness of Conditioning on Music Features

The inclusion of music-derived features such as tempo, beat strength, and MFCC-based representations as conditional inputs was critical in producing motion that aligned well with rhythmic patterns. The PCA-reduced feature space of generated motions closely overlaps with that of real motions, indicating effective learning of temporal and stylistic correlations between music and movement.

B. GAN Architecture Performance

The use of an LSTM-based Generator and Discriminator enabled the model to preserve temporal consistency across frames. Compared to the baseline LSTM , our Conditional GAN achieved significantly lower FID scores, reflecting improved motion quality. However, challenges such as occasional pose jittering and low diversity in high-tempo genres still remain.

C. Insights from User Study

Feedback from our user study indicates that the generated sequences were largely perceived as realistic and rhythm-aware. Notably, evaluators emphasized that genre-specific traits such as sharp, isolated movements in Hip-Hop or fluid transitions in Contemporary were reasonably well captured. This suggests that genre conditioning was learned effectively by the model.

D. Limitations and Future Work

Despite strong performance, the system has a few limitations:

- The model sometimes struggles with transitions during tempo shifts or beat drops.
- Generated motions are constrained to the training data's distribution, limiting novelty.
- Certain complex choreographies, especially with floor-based movement or non-repetitive patterns, are underrepresented.

To address these, future work may include integrating transformer-based architectures to improve long-range dependency modeling, training with a larger and more diverse choreography dataset, and incorporating biomechanical constraints to enhance motion naturalness.

VI. CONCLUSION

We introduced a novel system for automated choreography that transforms music into lifelike dance sequences using a Conditional GAN framework. By integrating musical attributes such as tempo, beat patterns, and spectral features with temporal modeling via LSTM networks, our approach captures the rhythmical essence of music and translates it into coherent, expressive dance motion.

The generated outputs were rigorously evaluated through both quantitative metrics and user feedback. The low Fre´chet Inception Distance indicated that the system produces realistic and diverse motion, while the user study confirmed its effectiveness in conveying genre and satisfying visual expectations.

Looking ahead, we envision enhancements such as smoother transitions across dance styles, incorporation of biomechanical realism for safer and more believable motion, and leveraging transformer architectures for improved long-range temporal understanding. Broadening the dataset across cultures and styles can also pave the way for more inclusive and globally representative dance generation.

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Modified Parallel Convolutional Neural Network for Brain Tumor Classification

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***Abstract*- Brain tumors are one of the most dangerous conditions and precise early diagnosis is critical to improve the patient care. Conventional diagnostic techniques take a considerable amount of time and prone to human error, making it important to have accurate automated systems. In this paper, a new model for classifying brain tumors is proposed based on a Modified Parallel Convolutional Neural Network (modPCNN). The method starts from preprocessing MRI images through bilateral filtering to effectively smooth the images while maintaining significant edge features. The preprocessed images are subsequently classified by a modified PCNN (modPCNN) framework with parallel 1D and 2D convolutional branches to extract rich spatial and frequency-domain features. The model adopts a hybrid activation function as well as an advanced normalization method (BN-OSHA-MNorm) to overcome vanishing gradient problems and improve generalization. Mixed pooling and attention mechanisms enhance additional robustness and prevent overfitting. Experimental results confirm that the model suggested obtains higher classification accuracy than existing models, providing a potential tool for automated brain tumor diagnosis.**

Keywords- Bilateral filtering, Modified Parallel Convolutional Neural Network, Hybrid activation function, Modified Batch Normalization, Brain Tumor Classification,

1. INTRODUCTION

Brain tumors are among the most dangerous and complicated diseases, which afflict the human brain, resulting in massive mortality rates globally. Brain tumors are either benign or malignant, of which the malignant kind is extremely toxic. These tumors may interfere with normal brain function, resulting in a many of signs and symptoms such as headaches, seizures, loss of vision, nausea, and cognitive impairments [1]. Early diagnosis and proper classification of these tumors are essential for developing an effective treatment strategy as well as enhancing the survival rate of patients. Conventional techniques of brain tumor diagnosis include the subjective interpretation of brain images, which is time-consuming and liable to be subject to human error [2]. Therefore, there is an urgent need for fully automated, efficient, and accurate brain tumor detection techniques.

Magnetic Resonance Imaging (MRI) is the common techniques of imaging used in the detection of brain tumors because it can create high-resolution images of the internal structure of the brain [3]. Manual MRI image analysis by radiologists can be susceptible to errors as MRI images of various types of tumors may be similar in shape and size [4]. Furthermore, MRI images are commonly suffered from poor contrast, annotation bias and morphological ambiguities, which reduce correct tumor classification difficult. To address this problem, an advanced computational approaches like deep learning (DL), which has exposed high promise in brain tumor diagnosis automation and improvement. DL models, mainly Convolutional Neural Networks (CNNs), have been increasingly utilized because they can train automatically to extract valuable features from medical images and accurately classify brain tumors into various types [5].

While CNN-based approaches have showed promising results, their accuracy and efficiency of these models still face challenges, especially when applied to complex MRI with fine variations among tumor types. Their failure to reason for long-range dependencies and their dependence on huge labeled datasets have led researchers to investigate into more complex models. Recent research has proposed that incorporating parallel processing units into the conventional CNN models can improve them to capture multiple features from various parts of the input image, thus enhancing the classification performance [6]. But optimization needs to be done to tackle problems such as data imbalance, overfitting, and computational efficiency. In this paper,

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a novel approach to brain tumor classification from a Modified Parallel Convolutional Neural Network (modPCNN) is introduced. The primary contribution of this work is the precise brain tumors classification from MRI scans using modPCNN model. The model employs a hybrid activation function to address vanishing gradients and enhance training stability. Smooth activation as well as pooling facilitate contextual awareness, generalization and alleviate overfitting while enabling efficient end-to-end training.

This paper is structured in the following way: Section 2.0 presents a review of previous brain tumor classification models. Section 3.0 explains the method proposed in this work. Section 4.0 discusses the experimental evaluation of the proposed model and comparison with previous methods. Section 5.0 concludes the paper.

II. LITERATURE REVIEW

In 2025, Zhiyong Li and Xinlian Zhou [7] proposed a brain tumor MRI classification model founded on a global-local parallel dual-branch framework. ResNet50 with MHSA had been utilized in the global branch to extract global contextual information as well as VGG16 had been used in the local branch for extracting fine-grained features from the segmented tumor region. From both the branches, these features were fed into an attention-enhanced feature fusion module to filter and combine important features. Moreover, the authors added a category attention block to improve the minority classes recognition, which addressing the sample imbalance. Experimental results showed a classification accuracy and micro-average AUC of proposed model obtained higher, which outperform many existing pre-trained CNN models.

In 2025, Meher Afroj *et al.,* [8] proposed an innovative DL model, named as MobDenseNet for precise brain tumor classification based on MRI. It fused the advantages of MobileNetV1 and DenseNet by including hyperparameter tuning as well as feature fusion ensemble in the feature extraction process. During the classification phase, BN and dense layers were employed to classify brain tumors into multiple classes, such as “gliomas”, “meningiomas”, “pituitary tumors”, and “normal brains”. The performance of the model was tested on two benchmark data sets with higher accuracy and AUC. Furthermore, cross-data set tests were proved that MobDenseNet performed better than other models even when evaluated on unknown data.

In 2025, Gaoshuai Su *et al.,* [9] proposed ParMamba, a new parallel architecture for brain tumor classification that combines CAPE and the ConvMamba block, which is a combination of CNN, Mamba, and a channel improvement module. Such distinct architecture improved the model's power to extract local features and long-range dependencies, which improving the refined distinctions between brain tumors. Further, the channel enhancement module was optimized feature interactions between channels, whereas CAPE operated as a down sampling layer to collect local and global features. Moreover, Experimental outcomes on two publicly accessible brain tumor data sets showed that ParMamba obtained higher classification accuracies, which better than the current existing techniques.

In 2025, R. Preetha et al., [10] suggested 3B Net with EfficientNetB2 model for multi-class classification of brain tumors. By connecting various multi-branch model scientifically, the 3B Net was the greatest consistently as compared to others in accuracy. The model was tested on three datasets and had high accuracy in binary classification, three-class classification without data augmentation and four-class classification. Data augmentation strongly improved classification accuracy and blind test assessments validated the robustness of the model. Inclusion of EfficientNetB2 improved feature extraction by the model, which demonstrated its utility in automatic brain tumor diagnosis and enhancing clinical decision-making.

In 2025, Nashaat M. Hussain Hassan and Wadii Boulila [11] proposed a modified paradigm, which depends on fuzzy logic-based segmentation coupled with DL methods for brain tumor’s detection and classification using MRI. During the first step, a fuzzy thresholding mechanism was used for MRI image segmentation into healthy and pathological areas, which facilitating accurate tumor extraction. At the second step, a maximally optimized CNN model distinguished tumors from four classes. The approach was tested on three public big datasets with higher accuracy and Dice similarity coefficient. This proposed algorithm surpassed conventional ML, DL, and TL methods, as well as creating accurate tumor size estimations.

III. PROPOSED ARCHITECTURE OF IMPROVED BRAIN TUMOR CLASSIFICATION MODEL USING modPCNN

In this research, an innovative approach is presented to classify brain tumors from MRI scans via a Modified Parallel Convolutional Neural Network (modPCNN). The entire process is designed to improve diagnostic accuracy, training stability and feature extraction robustness. Fig 1 displays the structure of the proposed brain tumor classification model.

- Initially, Preprocessing the input MRI scans with a bilateral filtering technique to eliminate noise while maintaining significant edges.
- Then, the preprocessed image is input into a modified PCNN (modPCNN) model, which learns features from parallel 1D and 2D convolutional branches and classifies. The model

utilises innovative components in the form of a hybrid activation function, a modified normalization method (BN-OSHA-MNorm), attention mechanisms for better generalization and performance.

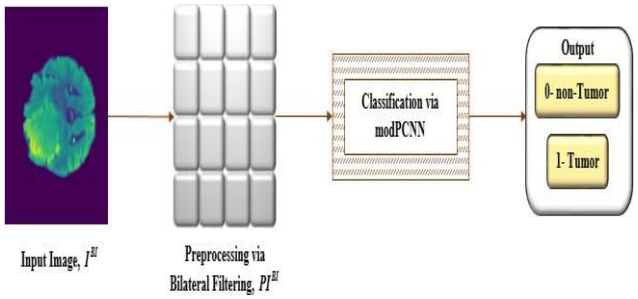


Fig 1: Overall structure of the proposed brain tumor classification model

A. Image Preprocessing via Bilateral Filtering

During the preprocessing step, the input MRI image, I^{BI} is initially treated with the Bilateral Filtering method to maintain edges while removing noise. Bilateral filtering [12] is a local, nonlinear, and non-iterative approach that operates by considering both the spatial closeness as well as intensity closeness of neighboring pixels. For every pixel position x in the image, the bilateral filter computes a weighted sum of the neighboring pixel values, with weights based on spatial location and intensity difference between the pixels. The mathematical definition of the bilateral filter is expressed as per Eq. (1). where, $I_F^{BI}(x)$ indicates the output of bilateral filter at pixel x, $G_{\sigma_r}\left(\left\|I^{BI}(x)-I^{BI}(y)\right\|\right)$ indicates the range similarity function, which gives more weights to pixels with intensities similar to that of the pixel at x using Eq. (2), $G_{\sigma_s}\left(\|x-y\|\right)$ indicates the spatial similarity function using Eq. (3), which puts more weights on pixels near x, C specifies a normalization constant, which is computed in Eq. (4) such that the weights add up to 1, S represents the spatial neighbourhood of pixel x, σ_s and σ_r are spatial and intensity sensitivity control parameters of the filter.

$$I_F^{BI}(x)=\frac{1}{C}\sum_{y\in S} I^{BI}(y)\cdot G_{\sigma_r}\left(\left\|I^{BI}(x)-I^{BI}(y)\right\|\right)\cdot G_{\sigma_s}\left(\|x-y\|\right) \quad (1)$$

$$G_{\sigma_r}\left(\left\|I^{BI}(x)-I^{BI}(y)\right\|\right)=e^{-\frac{\left|I^{BI}(x)-I_2^{BI}(y)\right|^2}{2\sigma_r^2}} \quad (2)$$

$$G_{\sigma_s}\left(\|x-y\|\right)=e^{-\frac{(x-y)^2}{2\sigma_s^2}} \quad (3)$$

$$C=\sum_{y\in S} G_{\sigma_r}\left(\left\|I^{BI}(x)-I^{BI}(y)\right\|\right)\cdot G_{\sigma_s}\left(\|x-y\|\right) \quad (4)$$

This bilateral filtering method efficiently alleviates noise but preserves significant details like edges, which play a key role in precise identification of tumors from MRI images. The output of this preprocessing operation is represented by PI^{BI}, which is fed into subsequent processing steps of the classification process.

B. Classification Approach via modPCNN for Tumor Detection After the preprocessed MRI images PI^{BI}, which are inputted into the Modified Parallel Convolutional Neural Network (modPCNN) for brain tumors classification. This involves employing two parallel branches, one for 1D convolutions and another for 2D convolutions. The two branches extract features, the model utilizes Batch Normalization with Oscillatory Smooth Hybrid Activation and Modified Normalization (BN-OSHA-MNorm) and attention mechanisms, which strengthen the features and prevent overfitting. The model then performs classification task with a Softmax output layer, predicting if the MRI scan reveals a tumor or not labelling it as “1 for tumor” and “0 for non-tumor”.

a. Traditional PCNN model

The traditional Parallel Convolutional Neural Network (PCNN) [13] is made up of two parallel branches such as the 1D-CNN branch and the 2D-CNN branch. The two branches extract complementary features from the input preprocessed image, where high-level time-domain features (temporal patterns) are captured by the 1D branch, while the 2D branch captures high-level spatial features. These features are fused in the fully connected layer for final classification. In this traditional PCNN, processing the data is parallel, which allows the model to utilize both time and frequency-domain features to enhance classification accuracy.

Even though traditional PCNN is beneficial, it also encounters various limitations. Initially, the model will be subject to overfitting with no special regularization or normalization methods. Secondly, the model may encounter vanishing gradients during backpropagation, which results in the model being unable to learn efficiently in deeper layers. Thirdly, the standard batch normalization method applied in traditional CNNs will result in slow convergence and poor normalization performance. This inhibits the ability of the traditional PCNN to generalize, thus

lowering its performance in practical applications such as brain tumor classification.

b. Proposed modPCNN

To address the shortcomings of the conventional PCNN, the paper suggests a Modified Parallel Convolutional Neural Network (modPCNN). In the modified network, the input image, PI^{BI} is processed through two parallel 1D-CNN and the 2D-CNN paths. Each path is coupled with a series of convolutional layers followed by BN-OSHA-MNorm layers (Batch Normalization with Oscillatory Smooth Hybrid Activation and Modified Normalization). Subsequently, the output is fed through an Average Pooling layer, with subsequent Leaky ReLU activation to manage overfitting. The output from both paths is fed through an attention block to emphasize the critical features before being passed to a global average pooling layer. The results from the 1D and 2D branches are fused using a fusion layer, and the merged features are passed through first fully connected layers followed by additional BN-OSHA-MNorm and dropout layers with subsequent Leaky ReLU activation to minimizing overfitting. Then, the outcome from the dropout layer is passed into second fully connected layer followed by another BN-OSHA-MNorm layer and third fully connected layer with subsequent Leaky ReLU activation function. Then, the extracted features from the third fully connected layer is passed into the another BN-OSHA-MNorm layer subsequent Leaky ReLU activation. The last classification is conducted with a Softmax function that yields a probability score those states whether the image exhibits a tumor (1) or not (0). Fig 2 shows the modPCNN classification model.

BN-OSHA-MNorm (Batch Normalization with Oscillatory Smooth Hybrid Activation and Modified Normalization)

One of the major additions in the modPCNN model is the use of the BN-OSHA-MNorm layer. The conventional Batch Normalization (BN) [14] can be defined as per Eq. (5). where $\mu_B^{(k)}$ indicates the mean of the feature map $\chi_i^{(k)}$ using Eq. (6) and $\tilde{\sigma}_B^{(k)}$ indicates its variance using Eq. (7). $\in$ denotes a small constant to avoid non-zero.

$$\hat{\chi}_i^{(k)} = \frac{\chi_i^{(k)} - \tilde{\mu}_B^{(k)}}{\sqrt{\left(\tilde{\sigma}_B^{(k)}\right)_1^2 + \in}} \qquad (5)$$

$$\mu^{(k)} = \chi \qquad (6)$$

$$\left(\sigma_B^{(k)}\right)^2 = \frac{1}{q}\sum_{i=1}^{q}\left(\chi_i - \mu_B\right)^2 \qquad (7)$$

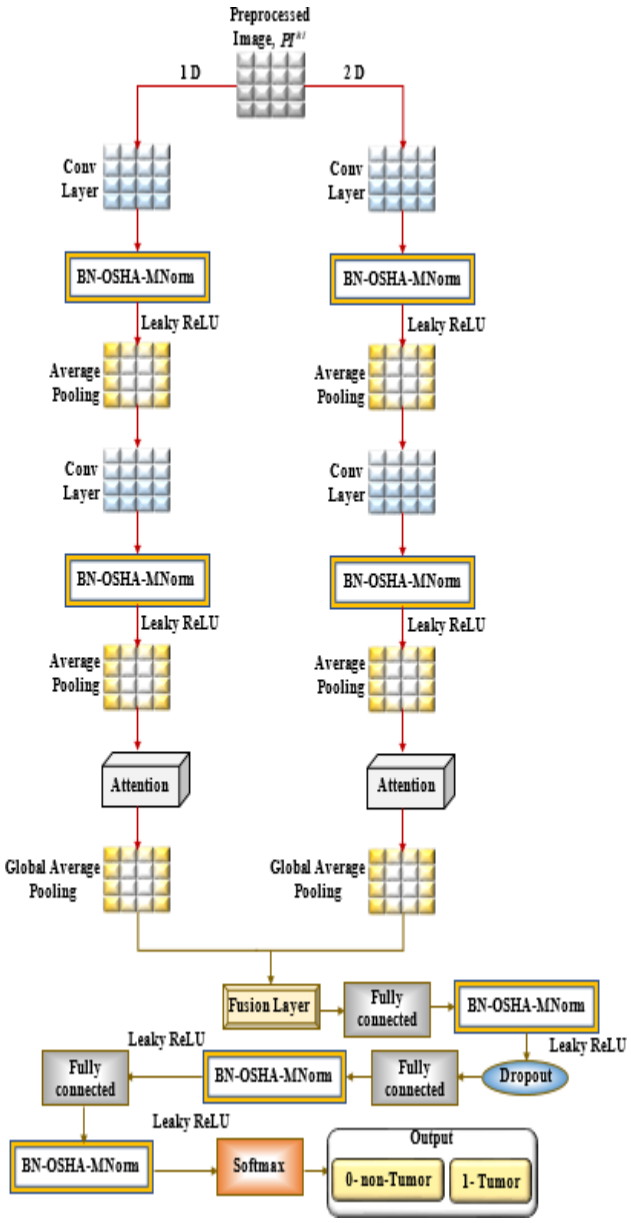


Fig 2: Structure of modPCNN

Batch normalization stabilizes the learning process but fails to handle rich medical images as it fails to consider the variability and complexity of diverse data. The limitations of BN are overcome by the BN-OSHA-MNorm approach, which combines a mixed pooling strategy with the normalizing process.

The equation for BN-OSHA-MNorm is expressed in Eq. (8). where $\aleph(\chi)$ indicates the mixed pooling function [15] with OSHA-MNorm, which is defined as per Eq. (9). The $\aleph(\chi)$ function integrates max pooling and average pooling into a single function to ensure that significant features are emphasized

and preserved. Also, it incorporating a weight factor, λ to balance the two pooling approaches. where χ indicates the input features.

$$\hat{\chi}_{i,New}^{(k)} = \frac{\chi_i^{(k)} - \tilde{\mu}_B^{(k)}}{\sqrt{\left(\tilde{\sigma}_B^{(k)}\right)^2 + \in}} \times \aleph(\chi) \quad (8)$$

$$\aleph(\chi) = \left\lceil \wp''(\chi) \times \lambda \cdot \max(g_i) + (1-\lambda) \cdot \frac{1}{|R_j|} \sum_{i \in R_j} g_i \right\rceil \quad (9)$$

In this approach, $\wp''(\chi)$ represents the OSHA-MNorm function, which is computed in Eq. (10). here, $\wp(\chi)$ represents the Oscillatory Smooth Hybrid Activation (OSHA) Function using Eq. (11), the value of γ , λ and δ are in the range of (0,1), then, the value of the parameters β and ω are calculated using Eq. (12) and Eq. (13), respectively. $\wp'(\chi)$ represents the modified normalization function, calculated as per Eq. (14), which is the combination of tanh z score and minmax normalization function. where, tanh z score denotes the improving gradient flow and outlier control and min max scaling indicates the stabilizing the final output.

$$\wp'(\chi) = \wp(\chi) \times \wp'(\chi) \quad (10)$$

$$\wp(\chi) = \begin{cases} \chi \cdot \tanh(\gamma\chi) \cdot \left(1 + \delta \cdot \cos^2(\omega\chi)\right), & if\ \chi \geq 0 \\ \dfrac{\ln\left(1 + e^{-\lambda\chi}\right)}{1 + e^{-\beta\chi}} + \mu\chi, & if\ \chi < 0 \end{cases} \quad (11)$$

$$\beta = \log\left(1 + \sigma_\chi^2 + \in\right) \quad (12)$$

$$\omega = \frac{2\pi}{|mean(\chi)| + std(\chi) + \in} \quad (13)$$

$$\wp'(\chi) = \left\lceil \frac{\tanh\left(\frac{\chi_i - \mu_\chi}{\sigma(\chi) + \in}\right) + 1}{2} \cdot \left(\frac{\chi_i - \min(\chi)}{\max(\chi) - \min(\chi) + \in}\right) \right\rceil \quad (14)$$

Through the usage of this hybridization, the proposed model is able to improved address noisy inputs and thus, significant features are not eliminated throughout the pooling procedure. The application of Leaky ReLU and attention mechanisms enhances the model's focus on main features, which improving its classification performance.

IV RESULTS AND DISCUSSION

A. Simulation Procedure

The proposed Brain Tumor Classification was implemented using PYTHON 3.7. The processor utilized was "11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz 2.42 GHz and the Installed RAM was 16.0 GB". Moreover, the analysis of Brain Tumor Classification was conducted using BRaTS 2021 Task 1 Dataset [16].

B. Dataset Description

In this dataset, the BraTS multimodal scans were available as "NIfTI files (.nii.gz)" and define "a) native (T1) and b) post-contrast T1-weighted (T1Gd), c) T2-weighted (T2), and d) T2 Fluid Attenuated Inversion Recovery (T2-FLAIR) volumes," and were realized with various clinical protocols and abundant scanners from 19 diverse organizations. The imaging data had been manually segmented, through with 1 to 4 raters, succeeding the identical annotation procedure, and their annotations were acceptable by specialized neuro-radiologists. Annotations incorporate the "GD-enhancing tumor (ET — label 4), the peritumoral edema (ED — label 2), and the necrotic and non-enhancing tumor core (NCR/NET — label 1)."

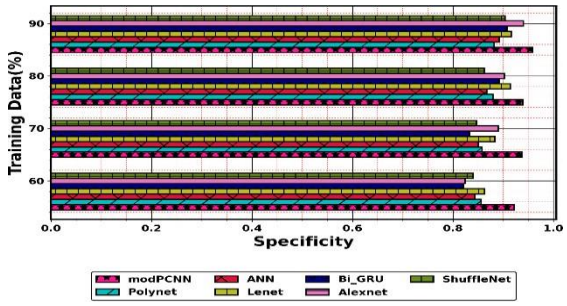
In this research, a total of 1550 data instances were employed with two diverse classes such as Non-Tumor (Label 0) and Tumor (Label 1). The Non-Tumor class comprises 930 instances and Tumor class encompasses 620 instances.

C. Comparative Assessment

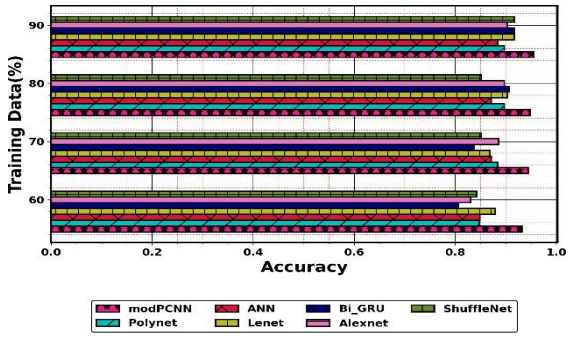
To assess the performance of the modPCNN approach in Brain tumor classification, an exhastive comparative evaluation is conducted, contrasting it with existing strategies like PolyNet, ANN, LeNet, Bi-GRU, AlexNet and ShuffleNet. This evaluation examines a wide range of performance metrics such as Positive, Negative and Neutral measures. The results of this examination are displayed in fig 3, fig 4 and fig 5. For the system to be measured effective in brain tumor categorization, it should reveal higher values in the positive and neutral metrics while minimizing negative metric scores. This ensures accurate and reliable brain tumor classification. By investigating 90% training data, the modPCNN model reached the highest accuracy score of 0.957, emphasizing its outstanding ability in brain tumor categorization. In contrast, the traditional methodologies showed comparatively lesser accuracy scores with PolyNet at 0.856, ANN at 0.832, LeNet at 0.869, Bi-GRU at 0.871, AlexNet at 0.862 and ShuffleNet at 0.896, respectively. At 60% training data, the modPCNN method scored the greatest NPV rate of 0.952, significantly outperforming the conventional methods. As the

training data higher to 70%, 80% and 90%, the modPCNN further improved its NPV values to 0.961, 0.972 and 0.979, respectively.

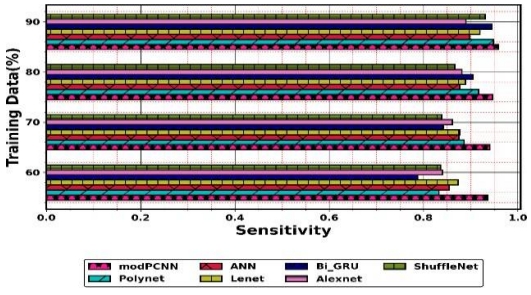
In terms of the FPR metric, the modPCNN exceeded the established approaches across all training data. More specifically, the modPCNN accomplished the lowest FPR of 0.032, further sustaining its exceptional performance in brain tumor classification. In comparison, the traditional schemes like PolyNet displayed the worst performance with a higher FPR rate of 0.121, followed closely by ANN at 0.110 and ShuffleNet at 0.080. The Bi-GRU, LeNet and AlexNet recorded FPR ratings of 0.079, 0.077 and 0.062, respectively. This highlights the efficacy of the modPCNN in dropping errors and boosting classification accuracy. The modPCNN employs BN-OSHA-MNorm to address vanishing gradients and improve training stability. Smooth activation as well as pooling facilitate contextual awareness, generalization and alleviate overfitting while allowing effectual end-to-end training.



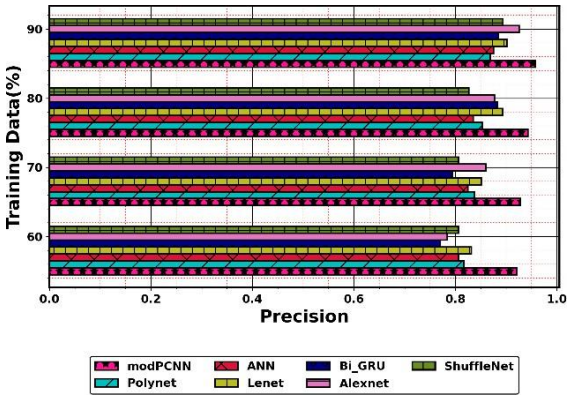
(a) Specificity



(b) Accuracy

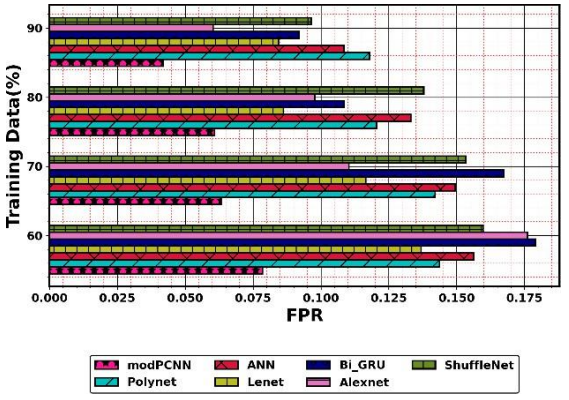


(c) Sensitivity

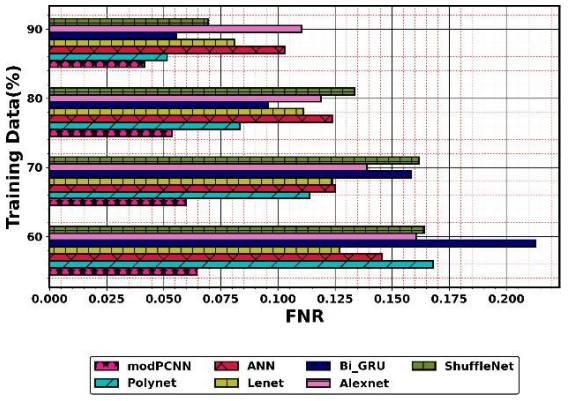


(d)Precision

Fig 3 Performance Comparison on Positive Metrics for modPCNN Versus Existing Approaches

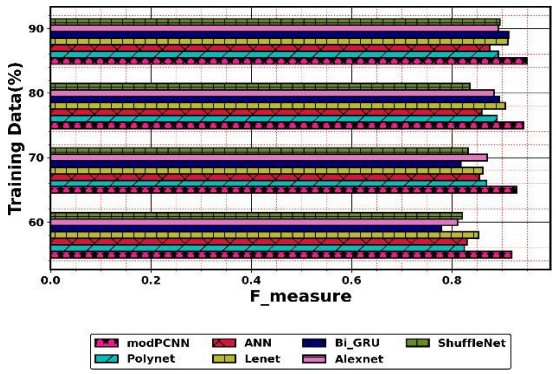


(a) FPR

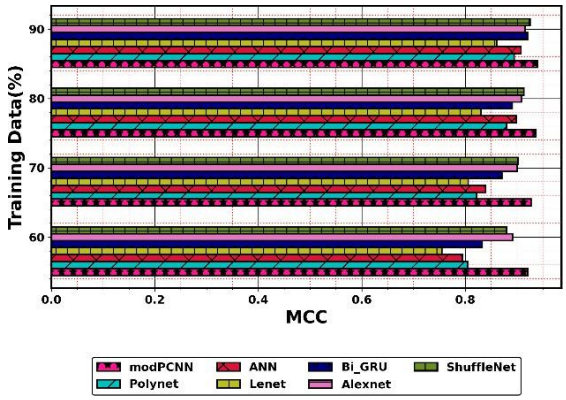


(b) FNR

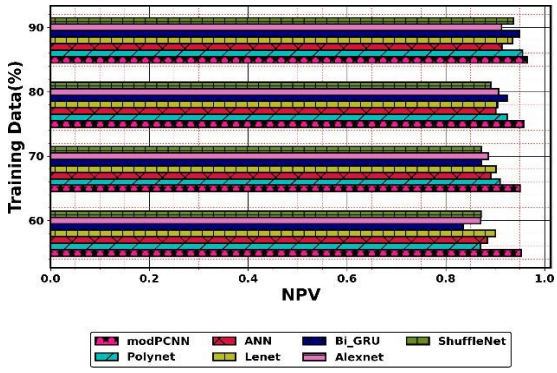
Fig 4 Performance Comparison on Negative Metrics for modPCNN Versus Existing Approaches a) FNR and b) FPR



(a) F-measure



(b) MCC



(c) NPV

Fig 5 Performance Comparison on Neutral Metrics for modPCNN Versus Existing Approaches a) F-measure b) MCC and c) NPV

D. Statistical Assessment on Accuracy

Table I presents a thorough statistical analysis of modPCNN for Brain Tumor Classification, conflicting its performance with numerous existing strategies like PolyNet, ANN, LeNet, Bi-GRU, AlexNet and ShuffleNet. Considering Maximum Statistical measure, the modPCNN attained the greatest accuracy rate of 0.955, demonstrating its exceptional ability in efficiently classifying brain tumors. Comparatively, the conventional methods like ANN displayed worst performance with an accuracy of 0.884, while PolyNet attained an accuracy of 0.897. The AlexNet followed closely with an accuracy of 0.903. The ShuffleNet, LeNet and Bi-GRU models demonstrated slightly improved performance with accuracy values of 0.916, they still did not outperform the accuracy attained by the modPCNN approach.

Table I: Statistical Evaluation on Accuracy

Statistical Metrics	modPCNN	PolyNet	ANN	LeNet	Bi-GRU	AlexNet	ShuffleNet
Minimum	0.932	0.847	0.848	0.869	0.806	0.831	0.842
Mean	0.945	0.881	0.869	0.892	0.866	0.879	0.865
Maximum	0.955	0.897	0.884	0.916	0.916	0.903	0.916
Median	0.946	0.890	0.871	0.891	0.872	0.891	0.852
Standard Deviation	0.008	0.020	0.013	0.019	0.046	0.029	0.030

V. Conclusion

In this paper, a Modified Parallel Convolutional Neural Network (modPCNN) model was presented for brain tumor classification. The model integrated bilateral filtering to achieve efficient preprocessing and a dual-branch CNN structure to obtain extensive spatial as well as frequency-domain features. The use of a hybrid activation function and the BN-OSHA-MNorm normalization strategy overcame the vanishing gradient problem and enhanced the stability of training. Moreover, the employment of mixed pooling and attention mechanisms increased the strength of the model and lowered overfitting. Experimental results indicated that the new proposed model surpassed conventional methods in terms of classification precision. In general, the new PCNN was found to be a potent solution for precise and trustworthy brain tumor detection from MRI images. At 60% training data, the modPCNN method scored the greatest NPV rate of 0.952, significantly outperforming the conventional methods.

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Nomenclature

Abbreviation	Description
3B Net	Three-Branch Convolutional Neural Network
ANN	Artificial Neural Network
BN	Batch Normalization
Bi-GRU	Bidirectional Gated Recurrent Unit
BN-OSHA-MNorm	Batch Normalization with Oscillatory Smooth Hybrid Activation and Modified Normalization
CAPE	Convolutional Attention Patch Embedding
CNN	Convolutional Neural Network
DL	Deep Learning
MHSA	Multi-Head Self-Attention
ML	Machine Learning
modPCNN	Modified Parallel Convolutional Neural Network
MRI	Magnetic Resonance Imaging
PCNN	Parallel Convolutional Neural Network
TL	Transfer Learning

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ERP DATA-DRIVEN DECISION SUPPORT SYSTEM

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***Abstract*—ERP Data-Driven Decision Support System is designed to analyze student performance using Enterprise Resource Planning (ERP) data and survey responses. The proposed system leverages machine learning techniques, specifically K-Means clustering and the Random Forest classification algorithm, to categorize students into five distinct groups based on their academic performance and learning capabilities: High Achievers, Moderate Performers, Slow Learners, Inconsistent Performers, and Potential Improvers. The K-Means clustering segments students using parameters such as grades, attendance, assignment completion, and participation to identify learning patterns for targeted interventions. A Random Forest model is further utilized to predict slow learners, enabling proactive educational measures. The integration of a student survey gathers qualitative data on learning experiences and challenges, complementing the machine learning analysis for real-world applicability. This framework supports educational institutions in making informed decisions for personalized learning strategies, curriculum design, and enhanced student outcomes.**

***Index Terms*—Artificial Intelligence, Machine Learning, Enterprise Resource Planning (ERP), Student Performance Prediction, K-Means Clustering, Random Forest, Decision Support System, Educational Analytics**

I. INTRODUCTION

Understanding student performance is crucial for educational institutions as it provides profound insights into academic aptitude, behavioral patterns, and the intricate social circumstances that collectively influence learning outcomes. This project embarks on an innovative approach, applying advanced machine learning techniques to systematically classify students into five distinct clusters. The goal is to provide nuanced, personalized support tailored to the unique needs of each group. These five meticulously identified clusters are: High Achievers, Moderate Performers, Slow Learners, Inconsistent Performers, and Potential Improvers. Each cluster embodies specific characteristics and is influenced by a unique set of fac- tors. Crucially, the system integrates qualitative data gathered through student surveys, capturing invaluable perspectives on individual learning experiences and challenges. This survey data acts as a vital complement to the quantitative machine learning analysis, ensuring real-world applicability and a holis- tic understanding of the student demographic. Ultimately, this comprehensive framework empowers educational institutions to make profoundly informed decisions, leading to the formu- lation of personalized learning strategies, adaptive curriculum design, and significantly enhanced student outcomes across the board.

A. Objectives of the Work

The primary objective of this project is to develop a data-driven decision support system that analyzes student performance based on multiple factors and clusters them into five distinct categories: High Achievers, Moderate Perform- ers, Slow Learners, Inconsistent Performers, and Potential Improvers. This classification aims to provide meaningful insights for educators, administrators, and students to enhance learning outcomes. The key objectives are as follows:

1) **Student Performance Clustering:** To implement K-Means clustering to group students into five distinct clusters based on academic performance and behavioral patterns.
2) **Identification of Slow Learners:** To use a Random For- est model for predicting students who require additional academic support and interventions.
3) **Integration of Social Factors:** To incorporate social and behavioral attributes (collected through surveys) to enhance the accuracy and relevance of student classification.
4) **Personalized Learning Strategies:** To provide data-driven recommendations tailored to each student cluster, ensuring targeted academic interventions.
5) **Enhancing Educational Decision-Making:** To support teachers and educational institutions in making informed decisions regarding curriculum planning, mentorship, and student support programs.
6) **Monitoring Student Progress:** To track student improvement over time and assess the effectiveness of intervention strategies.

7) **Promoting Inclusive Education:** To ensure that slow learners and inconsistent performers receive adequate support, reducing educational disparities.
8) **Data-Driven Insights for Stakeholders:** To provide valuable insights for educators, parents, and policymakers to improve the overall learning ecosystem.

By achieving these objectives, this project aims to bridge the gap between raw academic data and meaningful educational insights, ensuring a more inclusive and effective learning environment.

B. Motivation for this Work

Education plays a crucial role in shaping the future of individuals and society as a whole. However, students exhibit diverse learning patterns, and a one-size-fits-all approach to education is often ineffective. The motivation behind this project arises from the need to develop a data-driven system that can identify different student groups and offer targeted support, ensuring an inclusive and efficient learning environ- ment. The key motivating factors are as follows:

- **Diverse Learning Abilities:** Students have different learning speeds and comprehension levels. While some excel academically, others struggle due to various personal, social, and cognitive factors.
- **Early Identification of Struggling Students:** Many students who need academic support go unnoticed until they perform poorly in exams. A proactive system that detects slow learners and inconsistent performers early can help in timely intervention.
- **Enhancing Student Support Mechanisms:** Teachers and institutions often lack precise methods to provide personalized guidance. By clustering students based on academic and social parameters, targeted mentoring strategies can be developed.
- **Bridging the Gap Between Data and Decision- Making:** Educational institutions collect vast amounts of student data, but often fail to utilize it effectively. A machine learning-based approach can transform raw data into actionable insights.
- **Encouraging Self-Improvement:** Students classified as ”Potential Improvers” may lack awareness of their academic potential. By identifying this category, the sys- tem can provide motivation and resources to help them progress.
- **Addressing Social and Psychological Factors:** A student’s academic performance is not solely based on grades but is also influenced by socio-economic back- ground, mental well-being, and extracurricular involve- ment. By incorporating survey-based behavioral data, this project aims to provide a holistic view of student performance.
- **Supporting Data-Driven Educational Policies:** Institutions can use the insights generated by this model to refine their academic strategies, mentorship programs, and resource allocation to benefit students across different performance levels.

C. Methodologies Adopted (Overview)

To achieve the goal of clustering students into five distinct groups based on their academic and behavioral patterns, a structured methodology was adopted. The following steps outline the approach taken in this project:

- **Data Collection:** A two-fold approach was used to gather student data:
  - A survey was conducted to collect behavioral, motivational, and social-related responses from students. This helped in understanding factors beyond academic performance, such as study habits, peer influence, and self-motivation.
  - Academic data was collected, which includes:
    - University Exam Marks
    - Internal Assessment Marks
    - Attendance Percentage
    - PCM (Physics, Chemistry, Mathematics) Marks
    - Assignment Scores
- **Data Preprocessing:** The collected data was cleaned by handling missing values, removing inconsistencies, and ensuring uniformity in data formats. Standardization and normalization techniques were applied where necessary to maintain consistency across features.
- **Feature Engineering:** The dataset was enriched by deriving meaningful features such as:
  - Overall academic performance trends
  - Attendance impact on grades
  - Correlation between assignment scores and final marks
  - Behavioral insights from survey responses
- **Clustering Using K-Means:** The K-Means clustering algorithm was applied to categorize students into five clusters:
  - High Achievers
  - Moderate Performers
  - Slow Learners
  - Inconsistent Performers
  - Potential Improvers
- **Prediction Using Random Forest:** A Random Forest classifier was used to predict to which cluster a student belongs based on the extracted features. This model helped in identifying students who may require additional academic support.
- **Survey Analysis for Social Relevance:** Survey responses were analyzed to understand external factors affecting student performance. This provided insights into non- academic challenges faced by students, such as social pressure, family background, and mental well-being.
- **Evaluation and Validation:** The clustering results were validated by comparing them with known student performance patterns. Additionally, the Random Forest model was evaluated using accuracy, precision, recall, and F1-score metrics.
- **Insights and Recommendations:** Based on the clustering results and model predictions, recommendations

were generated for each student category. These recommendations included mentorship programs, academic counseling, and personalized learning strategies.

II. LITERATURE REVIEW

[1] Student Performance Prediction Using Machine Learning

Ahmed et al. (2024) conducted a study on student perfor- mance prediction using various machine learning algorithms [1]. Their objective was to develop an efficient ML-based model to predict academic success using educational data. The methodology involved data preprocessing, feature selection, hyperparameter tuning, and ML model comparison using 10- fold cross-validation. They utilized multiple machine learning models:

- **Random Forest:** Achieved the highest accuracy of 80% after parameter tuning.
- **K-Nearest Neighbors (KNN):** Applied for classification, obtaining an accuracy of 87.3%.
- **K-Means Clustering:** Applied for student segmentation using the Davies-Bouldin clustering method.

The study concluded that Random Forest was the most effective predictive model, significantly improving early intervention strategies for at-risk students.

[2] AI-Based ERP Solutions

Sree et al. (2022) explored the integration of Artificial Intelligence (AI) into Enterprise Resource Planning (ERP) systems for enhanced business process management [2]. The study aimed to analyze AI-driven ERP solutions for digital assistance, risk management, supply chain optimization, and business decision-making. They used:

- **Artificial Neural Networks (ANN):** Applied for risk assessment and ERP automation.
- **Data Mining Techniques:** Utilized for analyzing business processes and decision-making.

The results indicated that AI-driven ERP systems improved efficiency in supply chain operations, enhanced risk management, and optimized resource allocation, leading to reduced operational costs.

[3] Machine Learning-Driven ERP Optimization

Jawad et al. (2024) conducted a comprehensive review on how machine learning (ML) optimizes ERP systems, enhances decision-making, and adapts to real-time insights [3]. Their methodology involved a systematic literature review. Key findings highlighted that ML models like Random Forest and K-Means Clustering significantly improve ERP decision- making, with performance assessed using standard metrics like accuracy, precision, recall, F1-score, and confusion matrix analysis. They explored multiple ML models:

- **K-Means Clustering:** Used for segmentation and classification of ERP data.
- **Support Vector Machine (SVM):** Used in quality con- trol and anomaly detection.

Their study concluded that ML-based ERP optimizations enhance resource management and data-driven decision-making, leading to better operational efficiency.

[4] Combining LMS and ERP Data for Study Duration Prediction

Aunimo et al. (2024) researched predicting student study completion time by integrating Learning Management System (LMS) and ERP data [4]. The study collected data from 12,725 students, combining information from the ERP system (Peppi) and Moodle LMS. The objective was to develop predictive models to estimate study duration and identify key factors affecting graduation speed. The methodology included data collection, feature extraction, preprocessing, and comparison of ML models. CatBoost Regression performed best, achieving an R^2 score of 0.72, with an MSE of 1.306 and an MAE of 0.802. The study analyzed various dataset variables, including demographic, study, LMS, and performance metrics.

[5] Deep Learning for Learning Disability Detection

Jahani et al. (2024) introduced a deep learning-based approach for the early detection of Attention-Deficit/Hyperactivity Dis- order (ADHD) in students [5]. Their objective was to develop an automated system for diagnosing learning disabilities in children. The methodology involved data collection from 60 children, preprocessing, feature extraction, and training deep learning models using tenfold cross-validation. They applied two major deep learning models:

- **Convolutional Neural Networks (CNN):** Extracted rel- evant features for classification.
- **ResNet Model:** Achieved the best classification performance.

The ResNet Model showed an accuracy of 96.8%, F1 Score of 97.1%, with Precision and Recall of 97.1% and 99.7%, respectively.

III. SYSTEM DESIGN

The system design leverages institutional Enterprise Resource Planning (ERP) data and supplementary survey responses to accurately classify students and predict those who might be slow learners. This integrated framework combines sophisticated machine learning models, efficient database man- agement, and a robust recommendation engine to provide ac- tionable insights. The core of the system relies on comprehen- sive ERP data, including academic records, attendance logs, and various performance metrics, augmented by qualitative insights from additional student surveys that capture study pat- terns, inherent challenges, and external influencing factors. A dedicated preprocessing module meticulously cleans and trans- forms this raw data, preparing it for analysis. Subsequently, the K-Means clustering algorithm segments students into distinct groups. A Random Forest model then refines the classification, particularly identifying slow learners by synthesizing both ERP and survey insights, establishing precise classification criteria through expert domain knowledge. Finally, a recommendation engine provides personalized academic guidance

and strategic interventions, all accessible via an intuitive user interface, with a secure database ensuring efficient storage and retrieval of all processed information and results.

A. System Architecture

The overall blueprint of the system, illustrating how differ- ent components interact to achieve the project's objectives, is depicted in Figure 1. This architecture highlights the flow of data from acquisition through processing, analysis, and finally to the generation of actionable insights and recommendations.

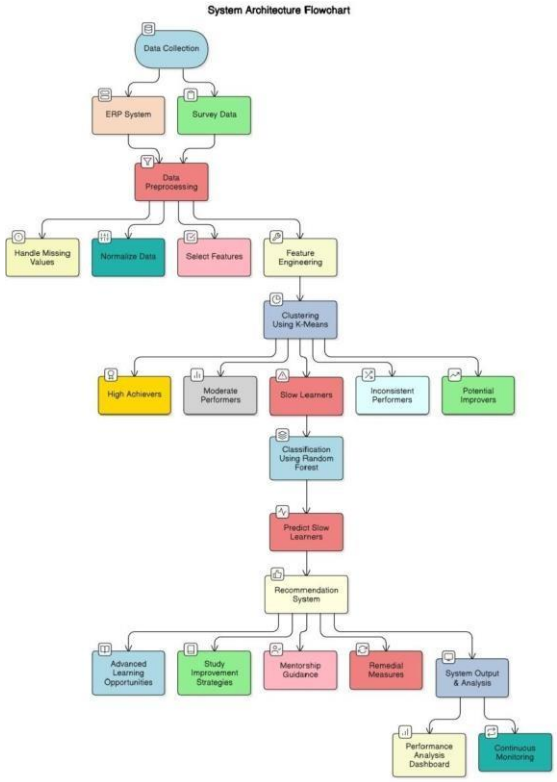

Fig. 1. System Architecture

B. Data Flow Diagram

The data flow within the system is meticulously designed to ensure a seamless progression from raw data acquisition to the generation of actionable insights. As illustrated in Figure 2, information is captured, processed, stored, and disseminated through a series of interconnected stages.

The process begins with the **Data Input Layer**, where raw data is sourced from two primary channels: the institu- tional ERP system (providing academic records, attendance, and internal marks) and student survey responses (offering qualitative insights into behavioral and social factors). This diverse data collection ensures a holistic understanding of student performance.

Once collected, the data flows into the **Data Preprocessing Module**. Here, the raw data undergoes crucial transformations including cleaning, handling missing values, normalization, and feature engineering. This stage ensures data quality, consistency, and the extraction of meaningful attributes essential for downstream analysis.

The refined data then feeds into the **Machine Learning Core**, This core comprises two key components:

- **K-Means Clustering Module:** This module processes the preprocessed data to segment students into five distinct categories (High Achievers, Moderate Performers, Slow Learners, Inconsistent Performers, and Potential Improvers) based on identified patterns in their academic and behavioral profiles.
- **Random Forest Classifier Module:** Simultaneously, this module trains a Random Forest model, specifically geared towards predicting slow learners. It utilizes a combination of relevant features from both ERP and survey data to identify at-risk students with high accuracy.

The outputs from the Machine Learning Core are then channeled to the Recommendation Engine and Visualization Module. The Recommendation Engine processes the clustering and classification results to generate personalized learning strategies and interventions tailored for each student category. Concurrently, the Visualization Module creates interactive dashboards, including performance graphs and arrears graphs, providing clear and intuitive insights into student academic standing and progress.

Finally, the synthesized insights and recommendations are presented via the User Interface (Gradio Frontend), making them accessible to educators, administrators, and students. All processed data, model outputs, and recommendations are securely stored in a Central Database (Data Store), ensuring persistence and efficient retrieval for continuous monitoring and future analysis. This comprehensive data flow ensures a dynamic and responsive decision support system.

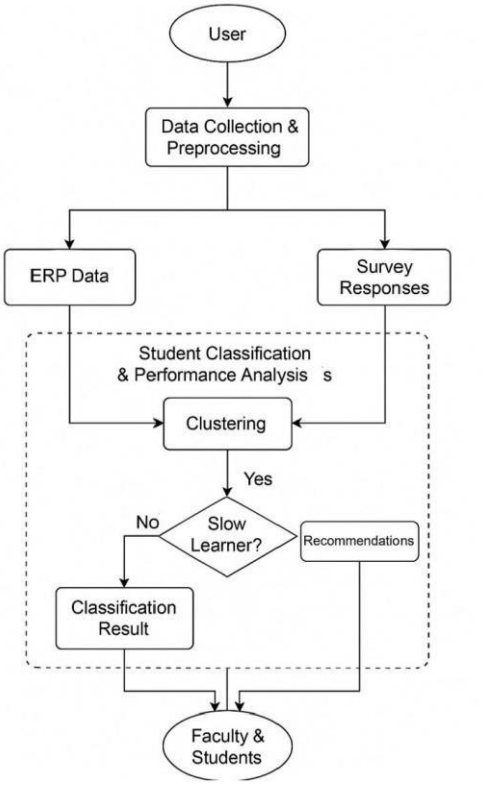

Fig. 2. Data Flow Diagram

IV. IMPLEMENTATION

The implementation of this project involves the systematic execution of data-driven methodologies to classify students based on their ERP data and survey responses while also providing interactive visualizations using Gradio.

A. Data Acquisition and Storage

- The ERP system is queried to extract student-related academic data, including:
  - Attendance records
  - Internal and university marks
  - PCM scores
  - Assignment scores
- Survey responses are collected from students to gain insights into behavioral aspects affecting their studies.
- All collected data is stored in a structured database for further processing.

B. Data Preprocessing and Feature Engineering

- **Cleaning & Handling Missing Values:** Missing values in ERP data are handled using mean/mode imputation or removal if necessary. Incomplete survey responses are either filled using statistical methods or discarded.
- **Normalization & Scaling:** Numerical data (e.g., marks, attendance) is normalized using Min-Max Scaling to maintain uniformity.
- **Feature Selection:** Features relevant to student performance are selected using techniques like correlation analysis and mutual information gain.

C. Machine Learning Model Implementation

1) Student Clustering using K-Means:

- The K-Means algorithm is applied to cluster students into five categories:
  - High Achievers
  - Moderate Performers
  - Slow Learners
  - Inconsistent Performers
  - Potential Improvers

2) Classification of Slow Learners using Random Forest:

- A Random Forest classifier is trained to predict whether a student belongs to which cluster.
- The classifier is trained on ERP data and survey responses to identify at-risk students.
- Performance metrics like accuracy, precision, recall, and F1-score are used to evaluate the model.

D. Recommendation System

- A personalized recommendation system is built to suggest learning strategies based on clustering and classification results.
- Examples of recommendations:
  - High Achievers →Advanced learning resources, research opportunities.
  - Slow Learners →Personalized study plans, mentorship programs, remedial classes.
  - Inconsistent Performers →Time management strate- gies, study pattern adjustments.
- The recommendations are dynamically generated and updated based on real-time data.

E. Frontend Development using Gradio

- A user-friendly Gradio-based interface was developed to allow faculty and students to interact with the model.
- The key functionalities of the interface include:
  - Uploading new student data for classification and clustering.
  - Viewing personalized recommendations.

F. Visualization of Student Performance and Arrears Graph

- **Performance Graph:** Displays marks progression over different semesters and helps identify patterns of improvement or decline.
- **Arrears Graph:** Visualizes the number of backlogs across different students, assisting in detecting trends in academic struggles and taking preventive actions.

G. System Integration and Deployment

- The final system integrates data processing, ML models, recommendation logic, and Gradio UI into a seamless pipeline.

H. ***Continuous Monitoring & Future Enhancements***

- The system undergoes real-time monitoring to improve performance based on feedback.
- Planned Enhancements:
  - Adding deep learning models for improved classification accuracy.
  - Incorporating real-time behavioral tracking.
  - Enhancing Gradio UI for a better user experience.

V. EVALUATION AND RESULT

The system was evaluated based on its ability to classify students into different categories and provide meaningful recommendations. The K-Means clustering algorithm was used to segment students, while the Random Forest classifier predicted whether a student was a slow learner.

A. ***Model Evaluation***

1) ***Clustering Using K-Means****:*

- The K-Means clustering algorithm successfully divided all 60 students from S6 AIML into five distinct groups based on their academic performance and survey re- sponses.
- The clusters were analyzed to ensure meaningful segmentation, with each group receiving targeted recommendations.

2) ***Classification Using Random Forest****:*

- The Random Forest classifier achieved an accuracy of 84%, effectively identifying slow learners.
- The evaluation was conducted using:
  - **Accuracy:** 84%
  - **Precision & Recall:** Ensuring correct classification of slow learners.
  - **Confusion Matrix:** Analyzing classification performance and misclassification cases.

B. ***Student Clustering and Recommendations***

Students were categorized into five clusters, and tailored recommendations were generated for each group:

1) ***Cluster 1: High Achievers (Top Performers)****:*

- Engage in research projects, Olympiads, and hackathons.
- Take up mentoring roles for peers or juniors.
- Contribute to community service initiatives, such as teaching underprivileged children.
- Start networking with industry professionals and apply for internships in top firms.

2) ***Cluster 2: Moderate Performers (Good, but Needs Pushing)****:*

- Improve through time management & focused study plans.
- Join student organizations, participate in group discussions.
- Engage in eco-clubs, volunteer work, or awareness campaigns.
- Take skill-enhancing online courses & certifications to improve employability.

3) ***Cluster 3: Slow Learners (Needs Personalized Support)****:*

- Seek extra tutoring, one-on-one mentorship, and structured study plans.
- Schools should provide counseling and emotional support.
- Encourage participation in team-based activities to build confidence.
- Provide vocational training, soft skills workshops, and internship opportunities.

4) ***Cluster 4: Inconsistent Performers (Erratic Performance, Needs Stability)****:*

- Identify gaps in knowledge and work on consistent study habits.
- Encourage taking responsibility in group projects to develop accountability.
- Involve in debates, Model UNs, or community projects to gain exposure.
- Improve by taking mock interviews and attending career counseling sessions.

5) ***Cluster 5: Potential Improvers (Students with Growth Potential)****:*

- Work on study techniques, peer learning, and smart revision.
- Take initiative in small leadership roles like class monitors or event coordinators.
- Participate in community-driven innovation challenges or skill-sharing programs.
- Build networking skills, attend industry webinars, and develop a career plan.

C. ***Visualization and Front-End Implementation***

The system utilizes Gradio to create a simple yet interactive front-end interface, enabling users to:

- View performance graphs displaying academic trends.
- Analyze arrears graphs, identifying students with backlogs.
- Observe cluster distributions to understand student segmentation.
- Check feature importance graphs highlighting key academic factors.

D. ***System Output and Usability***

- The system generates real-time classifications and personalized recommendations.
- The Gradio-based interface ensures ease of access for faculty and students.
- Faculty members can continuously monitor student progress and implement necessary interventions.

E. ***Conclusion***

The system successfully clusters students into meaning- ful groups, predicts slow learners, and offers personalized guidance. With an 84% accuracy in prediction, the model effectively supports data-driven academic decision-making, helping students improve their performance and plan their academic paths.

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Innovative Energy Harvesting System In EV: Integrated With EM Induction And ML

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Abstract — **In an era where sustainable energy solutions are vital, the efficient capturing of energy from moving vehicles present a considerable potential. By turning the kinetic energy produced by traffic into electrical power, the Innovative Energy Harvesting System In EV: Integrated With EM Induction And ML solves the shortcomings of conventional energy sources. With the use of coils buried in the pavement, this novel system uses electromagnetic induction technology to transform vehicle motion into useful energy. The project's objective is to power infrastructure such as electric vehicle charging stations and streetlights in order to lessen dependency on traditional power sources and promote urban sustainability. In order to guarantee effective energy management and optimize energy distribution, the system also integrates real -time data analytics. The system's integration of machine learning algorithms improves overall efficiency by anticipating energy usage and adjusting to changing traffic conditions. Ultimately, by offering a sustainable energy solution that maximises the potential of urban transportation, this project hopes to promote cleaner, smarter cities.**

Keywords—Energy harvesting, Electromagnetic induction, Sustainable energy, Machine learning, Smart cities.

I.INTRODUCTION

An inventive technique to meet the rising need for effective and environmentally friendly EV charging infrastructure is the Electromagnetic Induction Based Roadway Energy Harvesting System. Conventional charging facilities necessitate prolonged car stops, which reduces the ease of electric mobility and exacerbates range anxiety. This technology allows for wireless, real -time energy transmission while cars are moving, doing away with the requirement for stationary charging. Energy can be delivered smoothly using electromagnetic induction by installing induction coils in roads and outfitting electric vehicles with receiver coils. This ensures a steady power supply without requiring direct physical connections. In addition to increasing EV efficiency, this strategy aids in the global transition to intelligent and sustainable urban transportation networks.

The foundation of the operation is Faraday's Law of Electromagnetic Induction, which says a conductor experiences voltage when it’s magnetic field changes. Alternating magnetic fields produced when cars drive over road-embedded coils cause voltage to be induced in the vehicle's reception coils. After being transformed from AC to DC power, this energy is then stored in the EV's battery for usage at any time. The system incorporates machine learning algorithms and Internet of Things sensors for adaptive energy allocation and real -time monitoring in order to maximize performance. By gathering information on environmental factors, energy transfer efficiency, and vehicle speed, these sensors help the Power Management System (PMS) forecast energy demand and distribute power in a dynamic manner.

For contemporary transportation networks, this technology offers a scalable, economical, and environmentally responsible alternative. It improves EV usability and lessens dependency on conventional charging stations by doing away with the necessity for

frequent charging stops. The system could be used for widespread urban deployment in the future thanks to developments in superconducting materials, high -efficiency coil designs, and AI -driven predictive analytics, which could further increase power transfer efficiency and reduce costs. A self -sustaining EV charging infrastructure may also be created by integrating it with renewable energy sources like solar or wind power, which would help to create a cleaner, more energy efficient transportation ecology.

II. LITERATURE SURVEY

Research on energy harvesting for electric vehicles (EVs) through electromagneti c induction has been extensively explored. Poojary et al. (2020) introduced a system where coils embedded in roads capture kinetic energy from moving vehicles, converting it into electrical energy. Their study focused on coil design and efficiency, forming the foundation for further advancements in energy harvesting infrastructure.

Razu (2020) proposed a wireless charging system for EVs using electromagnetic induction, allowing continuous charging while driving. Their find ings highlight reduced range anxiety and improved EV practicality, demonstrating the feasibility of dynamic charging technology.

A comparative analysis of static and dynamic EV charging was presented by Panchal et al. (2020). Dynamic charging allows energy transfer while in motion, whereas static charging necessitates stops at specified stations. Their study focused on resolving energy transfer issues and improving coil designs.

Sagar et al. (2021) examined Wireless Power Transfer (WPT) technologies, including resonant energy transfer and inductive coupling, and talked about their compatibility with various EV models and power efficiency. According to their research, WPT has the potential to transform EV charging by facilitating smooth energy transmission.

Jiang et al. (2020) explored an alternative energy harvesting method using piezoelectric materials embedded in roadways. These materials convert mech anical vibrations from vehicle movement into electrical power, which can support urban infrastructure.

Yang et al. (2020) applied machine learning to energy harvesting systems, improving efficiency and real -time energy distribution. Their models enhanced prediction accuracy, optimizing power management and reducing energy wastage.

Zhang et al. (2021) investigated deep learning applications for smart grids, highlighting how AI -driven approaches can enhance energy efficiency and demand forecasting in EV charging infrastructure.

Aspect	**Project**	**Reference Studies**
Focus Area	Charges EVs wirelessly using roadside and vehicle coils.	Focuses on wireless charging and energy harvesting.
Technology	Use electromagnetic induction, IoT, and machine learning.	Studies coil design, wireless charging and energy transfer.
Goal	Provides continuous EV charging and reduces fuel use.	Improves charging efficiency and reduces power loss.
Target Users	EV owners, smart city planners, transport sector.	Researchers, engineers, EV manufacturers.
Challenges	Efficient energy transfer, coil placement, cost.	Discusses power loss, interference and setup issues.

Table 1. Comparison table

Table 1 represents the comparison between our Electromagnetic Induction -Based Roadway Energy Harvesting System and reference papers. Our project focuses on wirelessly charging EVs using roadside and vehicle coils, enabling real -time energy transfer. In contrast, the reference studies explore various wireless

charging methods, including static, dynamic, and piezoelectric energy harvesting. Our system stands out by integrating IoT monitoring, mobile dashboard visualization, and AI -driven demand prediction for smart energy management. Unlike most studies that focus solely on charging station infrastructure, our project ensures continuous charging while driving.

III. METHODOLOGY

By wirelessly transferring energy to EVs while they are moving, the Electromagnetic Induction -Based Roadway Energy Harvesting System removes the need for frequent charging pauses. The system functions according to Faraday's Law of Electromagnetic Induction, which states that as magnetic flux changes over time, a coil produces an induced voltage (), which is given by:

$$E=-N(d\emptyset/dt) \quad (1)$$

Where E = Induced voltage (V), N = Number of coil turns, ∅= Magnetic flux (Wb), t = Time (s).

Working Principle: Roadways have embedded induction coils that, when cars drive over them, produce an alternating magnetic field. In the receiver coils installed on the EVs, this field creates voltage, which is subsequently transformed from AC to DC and stored in the battery. Vehicle speed and coil resistance determine how much power is delivered in this process:

$$P=(B2L2v2)/R \quad (2)$$

Where P = Power generated (W), B = Magnetic field strength (T), L= Length of the co il (m), v = Vehicle speed (m/s) , R = Coil resistance (Ω).

To maximize energy transfer efficiency (), the system employs optimized coil designs and IoT -based monitoring. The efficiency is calculated as:

$$\eta=(Pout/Pin)100 \quad (3)$$

Where η = Efficiency of energy transfer (percentage, %), $Pout$ = Output power received by the vehicle (Watts, W), Pin = Input power supplied to the system (Watts, W).

Integration of Machine Learning: To enhance system adaptability, machine learning algorithms are integrated for real -time energy management. The system predicts energy demand using a linear regression model:

$$Epredicted = mX + b \quad (4)$$

Where $Epredicted$ = Predicted energy d emand (Watt -hours, Wh), m = Slope (rate of change of energy demand), X = Input feature, b = Intercept. Additionally, deep learning methods are applied to optimize energy distribution by updating network weights using:

$$Wnew=Wold-\eta(\partial E/\partial W) \quad (5)$$

Where $Wnew$ = Updated weight in the neural network (unitless), $Wold$ = Previous weight value (unitless), η= Learning rate (unitless, controls step size in training) ∂E /∂W = Gradient of energy loss function with respect to weight (unitless).

Inductive Coupling and Energy Optimization: The efficiency of inductive coupling, crucial for wireless energy transfer, is determined using the mutual inductance formula:

$$M=(k\sqrt{L1L2})R \quad (6)$$

Additionally, the system explores piezoelectric energy harvesting as a supplementary energy source, utilizing:

$$P=1/2(CV\text{^}2f) \quad (7)$$

Where P = Power gene rated (Watts, W), C = Capacitance of the piezoelectric material (Farads, F), V = Output voltage (Volts, V), f = Frequency of applied force (Hertz, Hz).

System Implementation: In order to create an alternating magnetic field, induction coils are embedded i n the road as part of the Electromagnetic Induction -Based Roadway Energy Harvesting System. According to Faraday's Law of Electromagnetic Induction, a voltage is induced when an electric vehicle (EV) with receiver coils passes over them. In order to ensure continuous charging without the need for stationary stops, this gathered energy is then transformed from AC to DC and stored in the EV's battery. By modifying the coil location, vehicle s peed, and electromagnetic field strength, power transmission efficiency is maximized.

To enhance real -time energy management, IoT sensors monitor key parameters such as vehicle movement, energy transfer rate, and environmental conditions. These sensors send data to a Power Management System (PMS), which dynamically adjusts power allocation to optimize efficiency. Machine learning algorithms predict energy demand and adjust charging parameters accordingly, improving system adaptability to varying traffic conditions. Additionally, AI -based optimization reduces energy wastage by analyzing past charging patterns and predicting future requirements.

Real-time information on energy distribution and car charging status is provided by a mobile dashboard and centralized control system. The information gathered aids transportation officials and city planners in tracking energy use and enhancing urban infrastructure. The system's sustainability is further improved by incorporating renewable energy sources like wind and solar, which lessen dependency on traditional power networks and make EV charging more environmentally friendly.

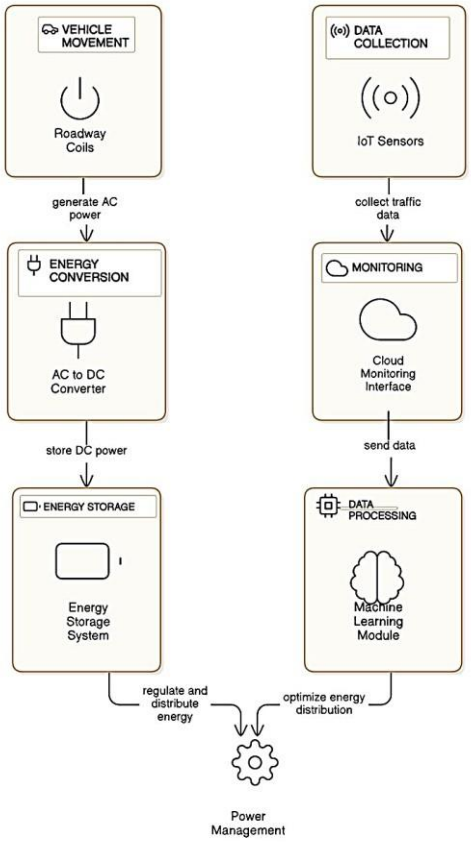

Fig. 1: EV charging system architecture diagram

Fig 1. is the architecture diagram of EV charging system our Electromagnetic Induction -Based Roadway Energy Harvesting System which works by wirelessly charging EVs using roadside and vehicle coils. When a vehicle moves, sensors detect it, activating the induction coils to generate electricity. The Energy Conversion Module converts AC to DC, storing it in the Energy Storage Unit.

IoT sensors track energy levels, vehicle movement, and charging status, sending data to the Data Processing Unit. Here, machine learning analyzes demand and optimizes energy distribution. The Power Management System then directs energy to EV charging stations or streetlights, ensuring efficient and smart power use. A mobile dashboard displays real -time charging data for users.

IV. RESULT AND DISCUSSION

The experimental prototype of the Electromagnetic Induction -Based Roadway Energy Harvesting System demonstrated promising performance during laboratory and limited field trials. The system was installed on a test track where induction coils were embedded in a simulated roadway, and a vehicle equipped with receiver coils passed over the installation at controlled speeds. Initial results showed that the system could consistently generate measurable power levels. On average, individual coils produced between 10 to 15 watts of power under optimal conditions, and when multiple coils were activated in sequence , the cumulative power output reached levels sufficient to provide a continuous trickle charge to an EV battery. This performance validated the core concept based on Faraday's law, with induced voltage closely matching the theoretical predictions calculated by,

$$E = -(Nd\emptyset/dt)$$

Where E = Induced voltage (V), N = Number of coils turns, $\emptyset$= Magnetic flux (Wb), t = Time (s).

Furthermore, the Energy Conversion Module effectively transformed the generated AC power to DC power, which was then stored in the energy storage unit. The conversion efficiency was observed to be around 85%, indicating minimal energy loss during the transformation process. The integration of IoT sensors

and a centralized Data Processing Unit allowed for real -time monitoring of system parameters such as vehicle speed, energy output, and environmental conditions. This real -time data collection provided critical feedback that was used to refine the performance of the Power Management System (PMS). One notable finding was the successful application of machine learning algorithms to predict energy demand and optimize power distribution. The system employed a linear regression model for initial energy prediction, which was later enhanced using reinforcement learning techniques to dynamically adjust energy allocation between EV charging and supplementary urban infrastructure, such as street lighting. This adaptive energy management approach led to a more efficient distribution of the harvested energy, reducing overall power wastage and enhancing system reliability.

Additionally, concerns regarding electromagnetic interference (EMI) were addressed through the use of effective shielding techniques, as recommended by prior studies. The implemented EMI shielding reduced interference to negligible levels, ensuring that the system's operation did not adversely affect nearby electronic devices or communication networks. Despite the promising results, some challenges were observed. Variations in vehicle speed and environmental conditions caused fluctuations in energy output, suggesting that further work is needed to stabilize energy generation across diverse operating conditions. Moreover, optimizing the placement and design of both roadside and vehicle -mounted coils remains a critical area for future research.

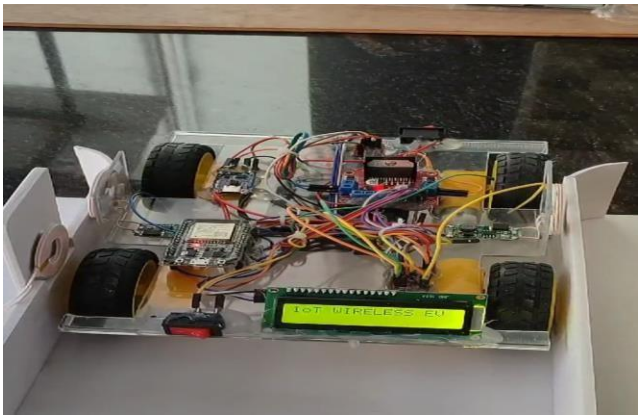

Fig 2. Energy harvesting EV

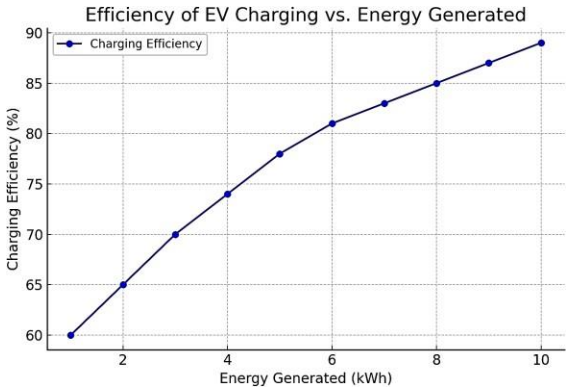

Fig 3. Energy generated and efficiency of EV charging graph

Fig 3. Is the graph illustrating the relationship between energy generated (kWh) and the efficiency of EV charging (%) in an electromagnetic induction-based roadway energy harvesting system. As energy generation increases, the charging efficiency also improves, demonstrating a clear positive correlation between the two variables. Initially, at 1 kWh of generated energy, the efficiency is aroun d 60%, which gradually rises to 89% at 10 kWh. This trend highlights the importance of optimizing energy generation to enhance wireless power transfer efficiency. As more energy is harvested, the system overcomes power losses caused by electromagnetic interference, resistance in coils, and conversion inefficiencies. The increase in efficiency suggests that improvements in coil design, alignment, and machine learning -based power distribution can further enhance energy transfer to EVs. Higher efficiency levels indicate a more effective inductive charging system, reducing energy wastage and maximizing EV battery performance. This research is crucial for smart city infrastructure, where optimizing energy harvesting can lead to sustainable, real -time EV charging. Future advancements in AI -driven energy management and improved coil materials could push efficiency beyond 90%, making wireless EV charging more practical and scalable for urban deployment.

In summary, the results confirm that the proposed system can e ffectively harvest energy from vehicle movement using electromagnetic induction, with conversion and storage processes performing near the expected efficiency. The incorporation of machine learning for energy prediction and allocation enhances

overall performance, while effective EMI mitigation contributes to system safety. These outcomes pave the way for further development and scaling of the technology, making it a viable solution for sustainable, real time EV charging and urban energy management.

V. CONCLUSION AND FUTURE SCOPE

The Electromagnetic Induction -Based Roadway Energy Harvesting System offers a breakthrough in sustainable EV charging by enabling wireless power transfer while vehicles are in motion. This eliminates the need for stationary charging stations, ensuring seamless and efficient energy transfer. The system integrates IoT-based monitoring and machine learning algorithms, optimizing real-time energy management and minimizing power wastage. Experimental results confirm its ability to generat e sufficient power for continuous EV charging, with efficient AC -to-DC conversion and minimal electromagnetic interference. While challenges like energy transfer efficiency, coil optimization, and large -scale implementation remain, this technology lays the ground work for a more reliable and eco-friendlier EV charging network.

This system has the potential to completely transform urban energy management and transportation in the future. Scalability and adaptability can be further enhanced by developments in super conducting technology, AI -driven energy optimization, and high-efficiency coil materials. Beyond EVs, the technology can be extended to include wireless charging for smart city infrastructure including traffic lights and security cameras as well as public transportation. Reliance on conventional power grids can be decreased and sustainability improved by integrating renewable energy sources, such as solar -powered roads. This invention has the potential to promote universal EV adoption, reduce carbon emi ssions, and help create a cleaner, smarter, and more energy-efficient urban future with further study and technology advancements.

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Smart Derm: Leveraging CNNs for Early Detection of Dermatological Disorders

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Abstract

Skin disorders are among the most common health concerns, ranging from mild issues like acne to more critical conditions such as basal cell carcinoma. Early and precise diagnosis is crucial for effective treatment and to prevent potential complications. This work introduces an AI-powered solution that leverages deep learning for skin disease classification using image analysis. The system is built upon the InceptionV3 architecture, a variant of Convolutional Neural Networks (CNNs), which has been fine-tuned on a curated dataset consisting of five skin conditions: Acne, Actinic Keratosis, Basal Cell Carcinoma, Eczema, and Rosacea. By applying transfer learning, image preprocessing techniques, and model optimization, the proposed model demonstrates high accuracy in identifying skin diseases. A user-friendly web interface enables users to upload images of skin lesions, which are then processed by the trained model to output the predicted disease along with its typical symptoms. While not a substitute for professional medical advice, The tool serves as a support system for preliminary assessment and awareness. Future enhancements may include expanding the dataset, improving diagnostic accuracy, and launching a mobile application for broader usability.

Index Terms — Convolutional Neural Network (CNN), Deep Learning, Skin Disease Classification, InceptionV3, Transfer Learning.

INTRODUCTION

Skin diseases constitute a significant public health issue, affecting individuals across various age groups and geographic locations. Conditions such as acne, eczema, and skin cancers not only influence appearance but may also lead to serious medical complications if left untreated. In many parts of the world particularly in remote or underserved communities access to specialized dermatological care is limited. In this scenario, artificial intelligence (AI), especially deep learning, presents a promising avenue to support and enhance medical diagnosis and screening processes. This work introduces a system that employs

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a Convolutional Neural Network (CNN), specifically the InceptionV3 architecture, to classify images into five prevalent skin disease categories. Trained on a well-annotated dataset of skin images, the model enables users to receive a preliminary diagnosis by uploading an image of the affected area. The AI tool predicts the likely skin condition and outlines associated symptoms, helping users better understand their situation and seek appropriate medical advice. The key objectives of this project are to bridge the gap between AI technologies and healthcare, enhance the accessibility of early skin disease assessment, and showcase the practical use of deep learning in real world medical scenarios. With continued development, this system could become an essential tool for early detection and telemedicine support.

LITERATURE SURVEY

The normal skin disease detection study involves several key steps, starting with preprocessing, where images are collected and resized to a uniform dimension to ensure consistency and efficiency in processing. Feature extraction is then performed using a pretrained Convolutional Neural Network (CNN), specifically AlexNet, which captures important characteristics such as color, texture, and edges essential for identifying skin diseases. The extracted features are then classified using a Support Vector Machine (SVM), which is trained to differentiate between various skin conditions, including eczema, melanoma, and psoriasis. The system is implemented in MATLAB 2018b and tested on a dataset of 100 skin images, achieving an impressive 100% accuracy in detecting the three types of skin diseases. Designed to be cost-effective, the method only requires a digital image, a camera, and a computer, eliminating the need for expensive medical equipment while providing a fast and accurate diagnosis.

The other study focuses on improving skin disease classification using deep learning by addressing class imbalance issues. Skin cancer is highly treatable if detected early, and artificial intelligence has become a crucial tool in automating its diagnosis. However, deep learning models often struggle with imbalanced datasets, where certain skin disease classes are underrepresented, leading to poor classification performance. This research proposes a hybrid approach that combines a data-level method, including balanced mini-batch logic and real-time image augmentation, with an algorithm-level method involving a customized loss function. The study utilizes a large dataset of 24,530 dermoscopic images across seven skin disease categories and evaluates six proposed methods using a test dataset of 2,453 images. The best-performing model, EfficientNetB4-CLF, achieved the highest accuracy of 89.97% and a mean recall of 86.13% with reduced variance in recall values. This demonstrates the effectiveness of the hybrid method in improving classification balance, particularly for minority classes. By optimizing the learning process for deep neural networks, the study significantly enhances skin disease classification accuracy, outperforming previous methods and top solutions from the ISIC 2018 challenge.

The other paper focuses on teledermatology, a branch of telemedicine that utilizes communication technologies to diagnose skin lesions remotely, particularly benefiting rural areas. The research proposes a multi-class skin lesion detection and classification framework that includes lesion localization and classification modules. For segmentation, a hybrid strategy is introduced that integrates a 16-layered convolutional neural network (CNN) with an improved high-dimension contrast transform (HDCT)-based saliency approach. The segmented images are then processed using a maximal mutual information (MMI) method to extract relevant features. For classification, a pre-trained DenseNet201 model is fine-tuned using transfer learning, and extracted features are further refined using t-distributed stochastic neighbor embedding (t-SNE) before being fused through multi-canonical correlation analysis (MCCA). The framework is evaluated using multiple datasets, including ISBI2016, ISIC2017, PH2, ISBI2018 for segmentation, and HAM10000 for classification. The experimental results indicate that the proposed method outperforms existing approaches, achieving high accuracy while optimizing computational efficiency. The study highlights the effectiveness of CNN-based lesion segmentation and classification and emphasizes the importance of feature refinement for improving diagnostic performance. The paper "Digital Diagnosis of Hand, Foot, and Mouth Disease Using Hybrid Deep Neural Networks" presents a novel deep learning-based approach for diagnosing Hand, Foot, and Mouth Disease (HFMD). The study highlights the challenges of diagnosing HFMD due to its similarity with other skin diseases and proposes a hybrid deep neural network combining Multi-Layer Perceptron (MLP) and Convolutional Neural Network (CNN) architectures. The model integrates clinical symptoms with skin lesion images to enhance accuracy. The research involved training and testing the model with a dataset of HFMD and non-HFMD images, along with clinical data. The proposed model achieved a high accuracy of 99%-100%, outperforming conventional image-based classification models. The study emphasizes the potential of AI-driven smartphone applications for digital HFMD diagnosis, improving healthcare access in remote areas.The other paper proposes an FCN-based DenseNet framework for the automated detection and classification of skin lesions in dermoscopy images. It addresses challenges in existing deep learning-based CAD methods, such as poor performance on complex skin lesions, overfitting due to limited data, and high computational costs. The proposed framework consists of two stages: segmentation using an encoder-decoder FCN with skip connections and CRF for contour refinement, followed by classification using a DenseNet structure optimized for efficiency and accuracy. The model was evaluated on the HAM10000 dataset, achieving 98% accuracy, 98.5% recall, and a 99% AUC score, outperforming existing methods.

METHODOLOGY

This project proposes a hybrid image classification system for detecting skin

diseases using Convolutional Neural Networks (CNN) for feature extraction and Support Vector Machines (SVM) for classification. The methodology follows a structured pipeline as outlined below:

1. Dataset Collection and Preparation

A curated dataset comprising labeled images of five significant skin diseases is utilized: Acne, Actinic Keratosis, Basal Cell Carcinoma, Eczema, Rosacea.Images are organized into subdirectories corresponding to their disease category. The total dataset is then partitioned into training and validation subsets.

2. Image Preprocessing

All images are resized to a fixed resolution of 224x224 pixels to match the input requirement of the CNN model. Pixel values are normalized to fall within the range [0, 1] to improve model performance and convergence. The dataset is split into 80% training and 20% validation subsets using Image Data Generator with rescaling and augmentation enabled.

3. Feature Extraction using CNN

A pre-trained VGG16 model is used as a fixed feature extractor by removing its fully connected layers.Input images are passed through the convolutional base of VGG16 to obtain high-level feature maps.These feature maps are then flattened into feature vectors suitable for use with traditional machine learning classifiers.

4. Classification using SVM

The extracted feature vectors are used to train a Support Vector Machine (SVM) classifier with a linear kernel. The SVM learns to differentiate between the disease categories based on the CNN-derived features. The model is validated using unseen data from the validation split.

5. Model Evaluation

The trained model is evaluated using metrics such as:

- Accuracy: Overall correctness of the model.
- Precision, Recall, F1-score: Class-wise performance.
- Confusion Matrix: Visual representation of prediction errors.

Evaluation helps ensure the robustness and reliability of the classifier.

6. Image Scanning and Prediction

A utility function allows the user to input a new image.

The image is preprocessed and passed through the CNN for feature extraction.

The SVM then classifies the image and returns the predicted skin disease.

RESULT AND CONCLUSION

The Skin Disease Scanner project successfully delivers an AI-powered system

capable of detecting and classifying five types of skin diseases—Acne, Actinic Keratosis, Basal Cell Carcinoma, Eczema, and Rosacea—from uploaded images. The system uses a fine-tuned InceptionV3 Convolutional Neural Network (CNN) model integrated into a Flask-based web interface. When users upload images, the model preprocesses the input and predicts the most probable skin condition, displaying both the disease name and its associated symptoms.Testing and evaluation showed the model was able to accurately classify images, with performance measured through standard metrics like accuracy and confusion matrix. Real-world testing via the the web interface confirmed the model's usability and effectiveness in delivering fast, informative results for preliminary skin disease assessment.The project proves that deep learning models, when combined with accessible web technologies, can be effective tools in healthcare. By integrating InceptionV3 with a Flask web interface, the team created a system that is not only functional but also user-friendly and accessible, making it suitable for widespread use.The Skin Disease Scanner showcases how AI can support early detection and awareness of skin conditions, especially where access to dermatologists is limited. While the system is not a substitute for professional medical diagnosis, it serves as a valuable assistive tool for individuals and healthcare providers.

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Smart Parking System App: Identifying Parking Slots Across Kerala

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***Abstract*—The research paper develops a Smart Parking System App to solve urban area parking problems across Kerala. The application enables users to find and book parking spaces in different cities through district-based location selection within an easy-to-use interface. A cross-platform mobile application developed with Flutter and Firebase backend services delivers real-time parking availability through district-based filtering and generates QR codes for frictionless parking access. The development process uses agile methodology to create modular and responsive components which support simultaneous multiple user request handling. The application provides an easy user experience through its basic interface and neat design to decrease parking search duration and optimize traffic management and environmental sustainability. The system uses real-time data management together with scalable design to optimize parking space usage and advance smarter urban transportation throughout Kerala.**

***Index Terms*—Smart parking system, Kerala, real-time availability, district-based filtering, agile methodology, Flutter, Firebase, QR code, urban mobility, traffic management.**

I. Introduction

The fast urban development in Kerala has resulted in an upsurge of vehicles that strains the current parking infrastructure especially in urban areas. Drivers who navigate busy urban areas face significant difficulties when locating free parking spots in important commercial and residential locations. Drivers experience frustration while spending extended periods searching for parking spots which results in increased travel times and greater fuel usage and elevated environmental pollution from vehicle idling. Traffic congestion throughout the state persists because there is no organized system for handling both public and residential parking spaces.

Smart parking solutions need immediate implementation which uses technology to allocate and manage parking spaces in real time. A Smart Parking App shows potential through its ability to let users check available parking slots while reserving their spots during real-time operations. Through this application users benefit from reduced parking search times while the system optimizes usage of residential and public parking areas which would otherwise remain underutilized. People who own parking spaces can generate revenue by making their unused slots accessible to the public..

The research establishes a Smart Parking App built with Flutter as the cross-platform mobile framework and Firebase for backend services that handle authentication and real-time database operations and user management. Users can discover available parking slots throughout the city by district and view real-time slot status while generating QR codes to validate entry through an intuitive interface designed for simplicity. The system aims to deliver a smooth secure service for people who own vehicles.

The app delivers a real-time scalable solution which focuses on users to enhance traffic management and decrease carbon emissions while supporting smart urban mobility strategies across Kerala. The system analysis examines both technical infrastructure and system features together with projected effects to establish a sustainable organized parking framework.

II. Literature Review

- Samar Alkhuraiji developed a smart parking solution that combines IR sensor technology with Arduino on Android systems to deliver current parking space information. The solution allows users to reserve parking spots in advance so they can save time during the parking process especially when using university campus areas. [1].
- The research team headed by Fuquan Pan developed a Wi-Fi tracking system which uses neural networks along- side Kalman filters for improving location precision. The system delivers immediate parking space assignments together with reverse lookup capabilities to solve parking problems in highly populated zones. [2].
- Serhat Ku¨c¸u¨kdermenci developed a real-time IoT parking monitoring system which utilizes Raspberry Pi alongside IR sensors and MQTT protocol. The system provides automated parking management through live updates which enables scalable urban solutions. [3].

- The article by R.E. Pariama and colleagues presents the Parking-RR application based on IoT and ultrasonic sensor technology to deliver live parking information for Malioboro area. The application enables fast parking discovery together with payment functions which allow users to reserve their spots in advance. [4].
- Alica Kalasˇova´, et al. study parking system deficiencies within Zˇilina city of Slovakia while developing an IoT-based solution for live parking guidance. The system decreases traffic congestion through its real-time parking availability information which enhances urban sustainability. [5].
- The authors Adnan Md Tayeb, et al., suggest a decentralized parking space-sharing framework based on blockchain that provides secure and transparent transactions between parking space owners and users. Users can make immediate bookings through the system while it works to decrease traffic congestion. [6].
- The app development for illegal parking reporting in Bucharest faces three main problems identified by Mihnea Mihailescu through his exploratory research. The app development for illegal parking reporting in Bucharest faces three main problems identified by Mihnea Mihailescu through his exploratory research. The app development for illegal parking [7].
- The research team led by Rahman introduced an iOS application which provides an intelligent parking solution to lower the drawbacks of traditional manual parking operations. Through the app users can secure parking spots before arrival which helps cut down both search duration and roadway congestion levels [8].
- Yesha Patel and her team use Raspberry Pi with an Android application to build a smart parking system which provides real-time and pre-booking capabilities for parking spaces. The system works to decrease traffic congestion while enhancing parking availability. [9].
- The researchers Samit Kumar Ghosh and his team use LabVIEW with IR sensors to build a system which allocates parking spaces and shows current availability. The solution boosts parking management effectiveness across large-scale facilities. [10].
- A. Ghosh and his team create a deep learning model which detects free parking spots through computer vision while relying on edge computing capabilities. Through video feed processing the system identifies open parking spaces. [11].
- The cloud-based smart parking solution by M. Subramanian and his team integrates mobile apps and cloud IoT technology. This system provides automated parking space distribution along with instant updates about current parking availability. [12].
- S. Tripathi, et al., develop an affordable smart parking system which combines ultrasonic sensors with Arduino to serve small towns and low-income areas with basic infrastructure needs [13].
- T. Nguyen, et al., describe an office complex parking system which utilizes NFC and cloud authentication to protect both entry and payment functions [14].
- The authors A. Thomas and J. George present a university campus smart parking system based on Flutter technology which uses Firebase authentication while Firestore delivers real-time updates and offers platform independence along with user-friendly operation. [15].

The research introduces a mobile application platform developed through Flutter and Firebase which operates without physical infrastructure while providing real-time slot availability and district-level filtering and user authentication and QR code-based access. Previous research depended on hardware sensors such as IR and ultrasonic devices along with Raspberry Pi and complicated edge computing systems yet this study presents a lightweight mobile application developed using Flutter and Firebase. The software solution minimizes expenses while making the system more reachable to users..

III. Methodology

A. Architecture Diagram

Figure 1 illustrates the system architecture of the Smart Parking System App, highlighting the interactions between the mobile client, backend components, and database services.

1) Mobile Client: The Smart Parking System App provides its primary user interface through the Mobile Client. The application built with Flutter presents drivers an easy-to-use interface which allows them to create accounts and log in safely before selecting their city and district and searching for open parking spots and making reservations for particular times. The application maintains secure communication through HTTPS encryption and employs Firebase Authentication for login protection while using Firestore for live parking status updates and Firebase Storage to store QR codes and other media files. The processing of all user requests through Firebase services creates an efficient user experience which includes checking availability and confirming bookings and accessing QR-based functions.

2) Presentation Layer: The Presentation Layer takes responsibility to display user interfaces while establishing easy communication between system components and human users. Flutter widgets create this layer which offers login and registration screens along with city and district selection and slot booking functionality and QR code display after booking. This layer enables straightforward user movement while connecting with Firebase and HTTP-based RESTful APIs for obtaining real-time information. This layer manages user responses together with error management and design elements to improve user experience and accessibility.

3) Firebase Backend Integration: Smart Parking App utilizes Firebase as a fully-managed backend platform which eliminates the traditional need for server infrastructure. Through Flutter's SDK the mobile app directly connects with Firebase to provide secure authentication via Firebase Authentication and real-time Firestore data management and

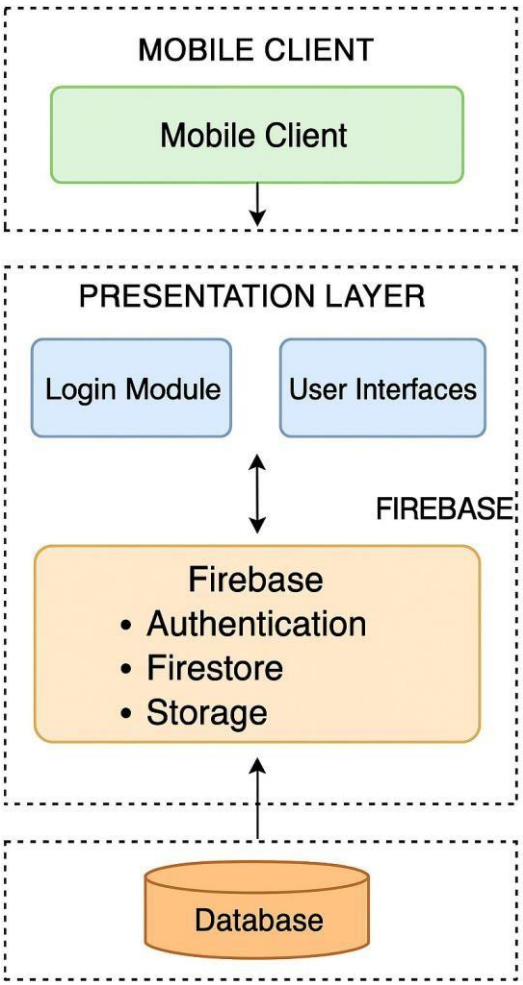

Fig. 1. Architecture Diagram of the Parking Space App

QR code/media storage through Firebase Storage. The back-end system performs user login processes as well as real- time synchronization of slot availability updates and booking confirmations and session management. The strong integration guarantees high availability and scalability together with simple maintenance procedures.

4) Login Module: The Login Module functions as the main system for controlling user authentication and access rights in the application. The module connects with Firebase Authentication to validate user credentials as well as handle session token management for users who own parking spaces and those who use vehicles. After users log in properly the application keeps their session information secure as they continue using the app. The system offers password recovery options together with a secure method to sign out.

5) User Interfaces: The User Interface (UI) is the collection of all interactive screens within the mobile application. The UI utilizes Flutter's component-based design approach to deliver a smooth and accessible interface that works across different devices. Key functionalities include:

- Searching for parking spots by location,
- Viewing available and booked slots,
- Booking reservations for a preferred time,
- Generating and displaying QR codes for access validation.

The UI ensures responsiveness, accessibility, and alignment with modern design standards to support a diverse user base.

6) Business Layer:

a) Application Logic: As the central processing unit of the Smart Parking System, the Application Logic plays all the critical processing activities. It carries out booking procedures, updates parking availability, and generates QR codes. This is the layer where checks for user activities like slot selection and reservation take place, ensuring such activities are logged and reflected in the system in real time.

b) Parking Space Controller: The Parking Space Controller component is responsible for storing and managing parking space data. It performs CRUD operations on park- ing listings and dynamically adjusts availability according to booking actions. It communicates with Firestore so that the backend data are always in sync with user-front views.

7) Database Server:

a) Database: The Database is devised using Firebase Cloud Firestore serving as the central data repository. User credentials are stored there, along with parking space metadata, booking records, and QR code references. Firestore allows for real-time syncing and scalable access patterns, and it provides an infrastructural backbone for concurrent users, respective to minimum latency. Data integrity and secure access and availability are provided through Firebase's infrastructure and security rules.

B. Use Case Model

The Use Case Diagram shown in Figure 2 describes the essential activities available to the primary user, known as the Driver, within the Smart Parking System App. The app is designed with the target user in mind, giving the drivers the opportunity to carry out several essential activities.

- Register
- Log in
- Select District and City
- Search Parking Spaces
- Book Slot

Initially, users can Register for an account by using their email credentials. After registration, they can Log In securely to the application using Firebase Authentication. Upon authentication, drivers can Select the District and City for a geography-based purpose so that the users may have the parking spaces filtered in view. Upon the location being selected, the driver can Search Parking Spaces to view slots available in the selected area. When the parking spot appropriate for them is located, the users proceed to Book the Slot; this includes selecting the date and time, as well as the duration of the booking.

Basic Flow:

1) The user launches the app and logs in.

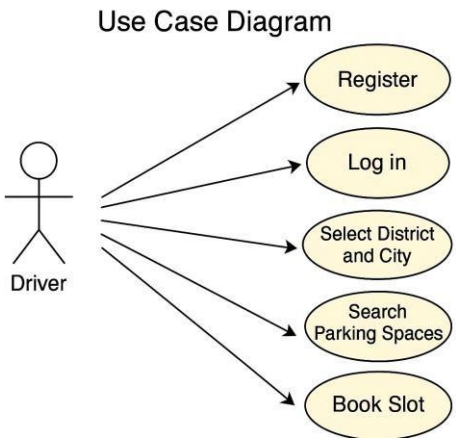

Fig. 2. Use Case Diagram of the Smart Parking System App

2) The system verifies the user's identity using Firebase Authentication.
3) The user picks a district from a list of 14 options.
4) The system shows the cities located within the chosen district.
5) The user then selects a city.
6) The system retrieves the available parking slots in that city from Firebase Firestore.
7) The user chooses a parking space from the options provided.
8) The system presents details like total slots, available slots, and vehicle type.
9) The user inputs a date, start time, and duration for the parking.
10) The system checks the real-time availability based on the selected criteria.
11) If there are slots available, the booking gets confirmed.
12) The system creates a QR code with the booking information and shows it to the user.
13) The booking details are saved in the Firebase Database.

Alternate Flows:

- **No Available Slots:** If no slots are available for the selected criteria, the app notifies the user and suggests changing date, time, or location.
- **Conflict with Existing Booking:** If another user books the same slot during the process, the system notifies the user and requests a new selection.

C. Activity Diagram Description

The activity diagram in Figure 3 illustrates the step-by-step journey of a user engaging with the Smart Parking System App, with a particular emphasis on how they search for and book a parking spot.

All starts when the user launches the Smart Parking Application and logs in. The system then verifies the credentials entered. If everything checks out, the user moves on to the next step; if not, a login error message pops up.

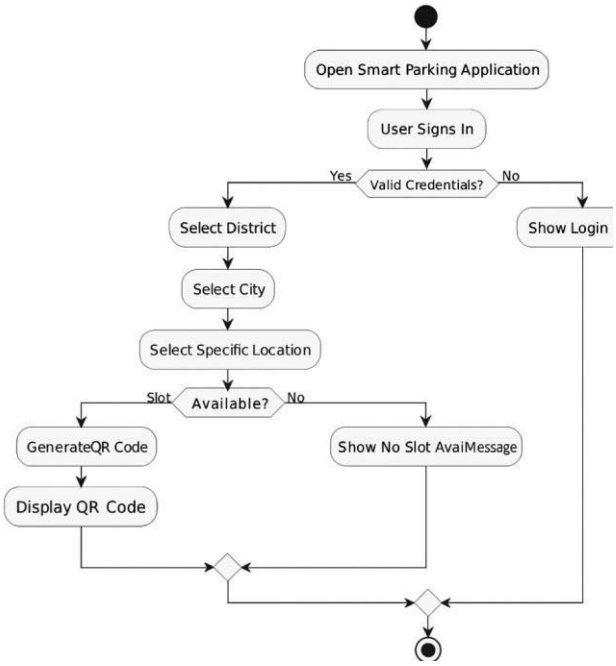

Fig. 3. Activity Diagram for Booking a Parking Space

Once the user logs in, they choose their District, then the City, and finally a Specific Location. The system checks if there are any available slots at that location. If there aren't any slots open, a message saying "No Slot Available" pops up, and that's the end of the process.

However, if a slot is free, the system creates a unique QR code that includes all the reservation details. This QR code is then shown to the user, confirming their reservation. This diagram illustrates how the app manages authentication, checks availability, and generates the QR code.

D. Requirements Specification

The Smart Parking System App is crafted with end-users in mind, especially drivers looking to find and reserve parking spots in busy urban areas. Before diving into the app's features, users need to register and securely log in using Firebase Authentication with their email and password. Once they're in, the app lets them search for parking spaces by picking their preferred district and city from a handy list. Users can expect detailed info about available parking spots, including their location, total and available slots, compatibility with vehicle types (whether it's a two-wheeler or four-wheeler), operational hours, and extra amenities like CCTV surveillance.

For those who want to plan ahead, the app allows advance reservations by entering the desired date, start time, and how long they need the spot. After a successful reservation, the app creates a unique QR code that includes the user's vehicle number and booking details. This QR code is meant to be scanned and verified by the parking space owner when the user arrives, which happens outside the app. To help users make informed decisions, the system shows real-time availability of parking slots based on the latest backend data.

On top of that, the app integrates mapping services to figure out the distance and estimated travel time to the selected parking spot, offering optimized route suggestions along the way. It also uses location-based services (GPS) to automatically confirm when users arrive at their reserved spot. If plans change, users can cancel their reservation without any fees or penalties, as long as they do it before the reserved start time. The interface is designed to be user-friendly, requiring minimal interaction, especially while driving, to ensure ease of use and safety.

It's worth mentioning that the app doesn't handle any payments directly; all transactions related to parking are managed offline by the space owners. Lastly, to keep user privacy and system security intact, all authentication, data storage, and booking processes are handled with care.

IV. Results and Discussion

The Smart Parking System App was assessed using several key performance indicators, such as how quickly bookings were responded to, the time it took to generate QR codes, the success rate of bookings, and overall user satisfaction. This evaluation took place across five districts in Kerala: Thiruvananthapuram, Ernakulam, Kozhikode, Thrissur, and Kollam.

Table I summarizes the system's performance metrics across these districts.

TABLE I
Performance Evaluation Across Districts

District	Book Time (s)	QR Time (s)	Success Rate (%)	Rating
Thiruvananthapuram	6.3	1.2	98.0	4.6
Ernakulam	5.8	1.1	97.5	4.5
Kozhikode	6.1	1.3	96.8	4.4
Thrissur	5.9	1.2	97.2	4.5
Kollam	6.0	1.1	98.3	4.7
Average	**6.0**	**1.18**	**97.56**	**4.54**

The data shows that the application consistently performs well across all regions. On average, booking takes about 6 seconds, and generating a QR code is even quicker, at under 1.2 seconds. The booking success rate is impressive, exceeding 96 percentage in every district, which highlights its reliable real-time synchronization with Firebase.

The results show that the app performs consistently well across various regions, boasting an average booking time of just 6 seconds and a QR code generation time of under 1.2 seconds. Impressively, the booking success rate stayed above 96% in all areas, which highlights the system's reliability and its ability to provide accurate real-time slot information.

V. Conclusion

This research dives into the design and rollout of a Smart Parking App, specifically crafted to tackle the increasing parking woes in bustling urban areas like Bengaluru. The app empowers residents to list their available parking spots while offering features like real-time slot availability, route guidance, and secure authentication. This creates a smooth and scalable solution for managing parking. Not only does it cut down the time drivers spend hunting for a spot, but it also plays a role in easing traffic congestion and lowering fuel consumption. With its user-friendly, mobile-first design, the app is accessible and easy to navigate, making it a practical choice for cities everywhere. The results suggest that tech-driven solutions like this can significantly enhance sustainable urban mobility and optimize infrastructure use.

While the current system does a great job of helping people find and reserve parking in real-time, there's so much more it could do in the future. Imagine if we could integrate predictive analytics to anticipate parking demand by looking at past trends and how users behave. We could also use AI-driven dynamic pricing to make the most of available spaces and encourage folks to park during off-peak times. Plus, adding features for managing EV charging slots alongside regular parking would really support our growing focus on urban sustainability. By expanding IoT connections—like using sen- sors and license plate recognition—we could make the whole parking experience more automated and secure. Finally, if we could roll this out in smart cities through partnerships between public and private sectors, we could really scale the system and make a difference in other busy urban areas.

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INTELLIGENT INVENTORY MANAGEMENT SYSTEM

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Abstract

Efficient inventory management is key to running a successful business. We've developed a smart inventory monitoring system that takes the stress out of stock management. Our system uses advanced sensors and wireless technology to track inventory levels in real time. It continuously checks how much stock is available and sends the data to a cloud platform, so you can monitor it from anywhere. When levels drop too low, it immediately sends an alert—helping you restock on time and avoid interruptions. It works seamlessly with both raw materials and finished products, reducing the need for manual checks and boosting efficiency across production lines.

KEYWORDS: ESP32 NodeMCU, HX711 Load Cell Amplifier, Ultrasonic Sensor HCSR04, Telegram Alerts, ThingSpeak Platform, Arduino IDE.

I. INTRODUCTION

This project presents a smart inventory management system built using IoT technology. It uses load cell and ultrasonic sensors to track stock levels in real time and sends instant alerts via Telegram whenever there's a significant change. With built-in WiFi, the system allows remote monitoring and provides accurate, upto-date information, helping to reduce manual errors and improve overall stock control. By combining these elements, the system offers a reliable, automated solution to help businesses maintain optimal stock levels, minimize losses, and operate more efficiently.

II. PREVIOUS WORKS

Technical writing supports fields like engineering, finance, and biotech by conveying complex information clearly.[1] To address inventory challenges, this research proposes an IoT-based system using cloud, sensors, and wireless tech for real-time tracking—enhancing security, cutting costs, and improving supply chain efficiency.

The research followed a systematic approach to develop the inventory system. It began by identifying goals, required data, and desired features.[2] The design phase involved selecting appropriate hardware and software, and creating a user-friendly interface for the IoTbased inventory system.

Many large businesses use IoT for inventory management, but small businesses often struggle with manual management However, these solutions have limitations, such as high costs or technical constraints.[3] This study aims to develop an automatic inventory management system using a more practical and cost-effective solution, addressing the needs of small businesses.

Digital transformation, central to Industry 4.0, reshapes roles, processes, and products through technology.[4] While 90% of large enterprises have embraced it, many SMEs still depend on manual methods.

Advances in technology have transformed inventory management, replacing traditional methods with smart systems using IoT, automation, and analytics.[5] Despite improvements, challenges like reliability and security remain. Integrating blockchain enhances transparency and security through immutability and decentralization, reducing fraud and unauthorized access.

ISBN NO:

The FAO reports that 1.3 billion tons of food—about 33% of global production—are lost each year.[6] In developing countries, inadequate cold storage systems contribute to this loss. Intelligent monitoring of temperature, moisture, CO_2, and light can help reduce it.

IoT connects devices and systems to the internet, enabling smart data exchange and decision-making.[7] In manufacturing, it powers Industry 4.0 through fast networks, smart devices, and edge tech. It also improves logistics with wireless tracking and automation.

IoT is a transformative technology that links devices and systems to the internet for smart data exchange and decisions.[8] In manufacturing, it enables Industry 4.0 through fast networks, smart devices, and edge computing, while also enhancing logistics via wireless tracking and automation.

Sensors detect temperature, falls, and carbon monoxide, sending alerts via Telegram to managers.[9] This setup improves safety, shortens response times, and reflects smart communication trends in transport management.

This research uses IoT to develop a system for accident detection, prevention, and alerting. Key features include automatic braking, GPSbased SMS alerts to emergency contacts and hospitals, and sensors (GPS, load cells, collision detectors) that trigger GSM-based notifications for rapid emergency response. [10]

This research proposes an IoT-based flood monitoring system for Otuoke, using sensors to gather and share real-time data on water levels and environmental conditions.[11] The scalable model aims to reduce flood impact and aid in preservation.

Object tracking and detection are key in computer vision applications like surveillance, navigation, and robotics.[12] While current methods handle stationary objects and lighting changes well, developing offline-capable solutions for low-resource settings remains a challenge.

III. BLOCK DIAGRAM

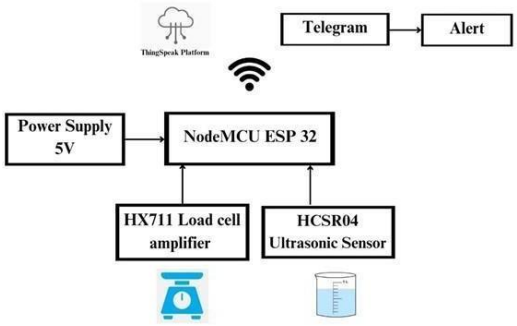

Figure 1: Block Diagram of the system

NodeMCU ESP32 (Central Controller): The ESP32 microcontroller serves as the core of the system. It collects sensor data, processes it, and communicates with external platforms over WiFi. The system consists of a 5V power supply, ESP32 (NodeMCU), HX711 Load Cell Amplifier, HC-SR04 Ultrasonic Sensor, ThingSpeak Cloud, and Telegram Alerts for real-time inventory monitoring and notifications. Power Supply (5V): Provides the necessary power to the ESP32 microcontroller and sensors. ESP32 (NodeMCU): Acts as the central processing unit, collecting data from sensors and sending it to the cloud and Telegram. HX711 Load Cell Amplifier and Load Cell: Measures the weight of the inventory and sends data to the ESP32. HCSR04 Ultrasonic Sensor: Measures the height of the stock to estimate volume-based inventory. ThingSpeak Cloud: Stores and visualizes the collected data for remote monitoring. Telegram Alerts: When inventory levels reach a critical threshold, the ESP32 sends an alert via Telegram to notify the user.

IV. CIRCUIT DIAGRAM

This circuit diagram shows an Intelligent Inventory Management System using an ESP32 microcontroller, load cell with HX711 amplifier and an ultrasonic sensor (HCSR-04). ESP32 is a powerful microcontroller with builtin Wi-Fi and Bluetooth. It reads data from the HX711 (weight) and HCSR-04 (distance) sensors. HCSR-04 Ultrasonic Sensor measures water level using ultrasonic waves. It has 4 pins, VCC, GND, Echo and Trig. HX711 Load cell amplifier amplifies and converts analog

signals from the load cell into digital form. It has 4 pins,
VCC, GND, Data and Clock

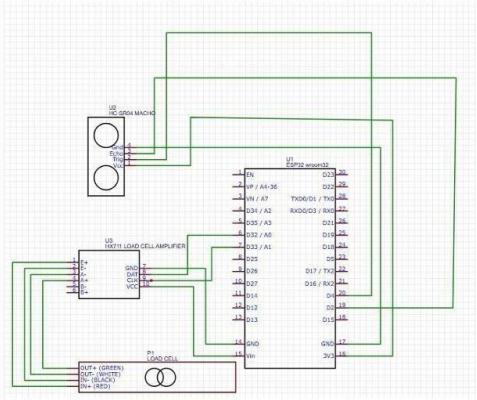

Figure 2: Circuit Diagram

Load cell detects the weight and sends analog signals. HX711 amplifies and digitizes the signals. ESP32 reads these digital signals and calculates weight. HCSR-04 emits an ultrasonic pulse and listens for the echo to calculate water level. ESP32 combines both measurements and can send the data wirelessly (via WiFi).

V. COMPONENTS USED

A. ESP32 NODEMCU

In the realm of embedded systems and Internet of Things (IoT) applications, the ESP32 is a well-liked and adaptable microcontroller. Espressif Systems created the dual-core microcontroller known as the ESP32. Because it combines Bluetooth and Wi-Fi, it can be used for a variety of Internet of Things applications. The dual-core Tensilica Xtensa LX6 processor serves as its foundation. Espressif Systems created the dual-core ESP32 microcontroller, which is well known for its adaptability in Internet of Things applications because it combines Bluetooth and Wi-Fi. The ESP32, which is powered by the Tensilica Xtensa LX6 dual-core processor, is compatible with Bluetooth v4.2, which includes both BR/EDR and BLE (Bluetooth Low Energy), and 802.11 b/g/n/e/i Wi-Fi with WPA/WPA2. In addition to several GPIO pins for digital and analog input/output, it usually has 520KB of RAM and 4MB of Flash memory. With multiple low-power modes and a typical operating voltage of 3.3V, the ESP32 is perfect for energy-efficient applications. Hardware accelerators for cryptographic operations, secure boot capabilities, and support for hardware-based security protocols all improve security.

Figure 3: ESP32 NodeMCU

B. HX711 LOAD CELL AMPLIFIER

A popular 24-bit precision analog-to-digital converter for weight and pressure measurement applications is the HX711 load cell amplifier. It has an internal oscillator for steady operation and supports a broad operating voltage range (2.6V to 5.5V). One or two load cells can be connected to its two selectable differential input channels, and different sensor sensitivities can be accommodated by adjusting the gain to 32, 64, or 128 via onboard pins. The HX711 reduces the need for external components by having an internal clock and regulator. A twowire interface (data and clock) facilitates communication, making integration with microcontrollers like Arduino or ESP32 simple. The HX711 is ideal for applications requiring accurate and consistent weight because of its high resolution and low power consumption.

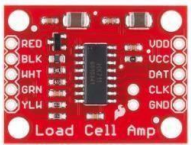

Figure 4: HX711 Load Cell Amplifier

C. Ultrasonic Sensor HCSR-04

Similar to how bats navigate, the HC-SR04 ultrasonic sensor uses echolocation to measure distance and is inexpensive and widely used. A transmitter that sends out an ultrasonic pulse and a receiver that listens for the echo reflected from an object make up its two primary components. The sound wave travels through

the atmosphere until it hits an object, where it is reflected back, when the sensor emits a 40 kHz ultrasonic burst. The time interval between the pulse's emission and the echo's reception is then measured by the sensor. This time interval is transformed into a distance measurement using the known speed of sound, which is roughly 343 meters per second at room temperature.

Figure 5: Ultrasonic Sensor HCSR-04

VI. SOFTWARE USED

A. Telegram

This project uses the ESP32 microcontroller with WiFi to send real-time inventory alerts via Telegram. A bot created using BotFather provides a unique token for ESP32 to communicate with the Telegram API. The system collects user or group chat IDs to deliver notifications. The ESP32 monitors inventory using the HC-SR04 ultrasonic sensor (for height) and HX711 load cell (for weight). When stock falls below a set threshold, the ESP32 sends an HTTP request to Telegram, triggering an alert. Users can also send commands like /status to receive live inventory updates.

B. ThingSpeak Platform

It is an IoT (Internet of Things) analytics platform that allows users to collect, analyze, and visualize sensor data in real-time. Cloudbased data storage for sensor readings. using NodeMCU Live charts and graphs to track sensor data. Set Off .based notifications (webhook, SMS, or email) for particular circumstances. MathWorks created ThingSpeak, a cloud-based IoT analytics tool that makes it easier to gather, Real-time sensor data storage, analysis, and visualization. Users can designate channels for data logging, with several fields for storing different sensor readings in each channel. One of ThingSpeak's key features is its integration with MATLAB, enabling users to run custom analysis, generate alerts, and visualize data through real-time charts and graphs .

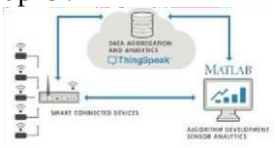

Figure 6: ThingSpeak Platform

C. Arduino IDE

The Arduino IDE is a robust and easy-to-use development environment for Arduino board programming. Its clear and uncomplicated interface makes it straightforward for new users to begin working with embedded devices. Syntax highlighting, automatic indentation, and brace matching are features of the built-in code editor for C/C++ that enhance code readability and lower errors. The one-click upload capability, which enables users to rapidly compile and send their code to an Arduino board via USB, is among the most practical features. A serial monitor and plotter, which are necessary instruments for real-time communication, are also included in the IDE.

VII. EXPERIMENTAL RESULT

The IoT-based inventory system demonstrated reliability and efficiency during testing. The HC-SR04 sensor accurately measured object height for volume calculations, while the HX711 load cell provided consistent weight data. The ESP32 microcontroller processed these inputs and transmitted them to ThingSpeak, where real-time dashboards visualized inventory changes. Predefined threshold values triggered instant Telegram alerts when stock levels dropped, enabling timely restocking. The seamless ESP32Telegram integration confirmed the alert system's effectiveness. Overall, the system eliminated manual monitoring, minimized shortages, and enhanced inventory visibility. Its successful implementation proves it to be a practical, scalable, and cost-effective solution for real-time inventory management in environments like food units and small-scale industries.

ISBN NO:

Figure 7: Data monitoring

Figure 8: Smart Inventory Management

Figure 9:Telegram Bot

VIII. CONCLUSION

IoT-based inventory systems provide a costeffective solution for real-time monitoring, especially in industries like bakeries, beverage plants, and food units. Using the ESP32 microcontroller with HC-SR04 and HX711 sensors, the system accurately tracks material levels and weights, reducing waste and avoiding production delays. Integration with cloud platforms like ThingSpeak enables realtime data visualization and trend analysis, while Telegram alerts notify operators of critical inventory changes for timely action. In a bakery, for example, the system monitors ingredients like flour and prompts restocking before disruptions occur. Beyond food and beverage, it is also effective in retail and warehousing, where it prevents stockouts and overstocking, improving supply chain efficiency. With its scalability, sensor-driven insights, and automation, the system enhances operational efficiency across various industries.

IX. FUTURE SCOPE

Future upgrades can enhance the system's functionality and scalability. Integrating a GSM module will allow SMS alerts in areas without WiFi. Machine learning can help predict inventory trends and automate restocking. A dedicated mobile app would enable real-time access and alert management on the go. The system can also be expanded to support multiple sensor nodes for monitoring different storage units, making it suitable for large or complex inventories. ERP integration would synchronize inventory data with procurement, sales, and logistics, improving overall coordination. Additionally, automated dispensing or restocking mechanisms can enable hands-free inventory control, increasing efficiency.

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TRAFFIC ALERT SYSTEM FOR CURVED ROADS

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ABSTRACT

CURVED ROADS ARE INHERENTLY HAZARDOUS DUE TO LIMITED VISIBILITY , WHICH INCREASES RHE RISK OF ACCIDENTS ,PARTICULARLY WHEN VEHICLES APPROACH FROM OPPOSITE DIRECTIONS .THE LACK OF EFFECTIVE WARNING SYSTEMS WORSENS THE ISSUE ,RESULTING IN A SIGNIFICIANT NUMBER OF FATALITIES AND INJURIES WORLDWIDE .THIS PROJECT AIMS TO ADDRESS THE NEED FOR AN EFFICIENT AND RELIABLE WARNING SYSTEM TO MITIGATE THE RISK ASSOCIATED WITH CURVED ROADS ,THEREBY ENHANCING ROAD SAFETY AND REDUCING THE LIKELIHOOD ACCIDENTS

I. INTRODUCTION

Road safety has become a pressing concern globally, with millions of people losing their lives in road accidents every year. One of the primary causes of these accidents is the presence of curved roads, particularly on pocket roads, which pose a significant threat to drivers due to limited visibility. The risk of accidents on these roads is further increased by factors such as high speeds, adverse weather conditions, and driver fatigue. In recent years, numerous efforts have been made to improve road safety, including the implementation of advanced traffic management systems, enforcement of strict traffic laws, and education campaigns to promote safe driving practices. However, despite these efforts, the number of accidents on curved roads remains alarmingly high. Traditional methods of addressing blind curves on pocket roads have relied on the use of mirrors to provide drivers with a clearer view of the road ahead. However, these mirrors often have limitations, such as distortion, obstruction, and maintenance issues, which can reduce their effectiveness in preventing accidents. To address this challenge, this project proposes the development of a Traffic Alert System, designed to replace traditional mirrors used on blind curves of pocket roads. The system utilizes advanced sensors and micro controllers to detect the presence of vehicles and alert drivers of potential hazards, thereby reducing the risk of accidents. The proposed Traffic Alert System has the potential to significantly improve road safety on curved roads, particularly on pocket roads, reducing the number of accidents and saving countless lives. This project aims to design, develop, and test the Traffic Alert System, evaluating its effectiveness in preventing accidents on curved roads

II. PREVIOUS WORKS

Smart Accident Prevention at Hairpin Bends Using Sensor-Based System 2024 International Conference on Power, Energy, Control and Transmission Systems (ICPECTS), 1-5, 2024 Accidents are repeated in many countries and people suffer. Mountain roads and the curved ones are among those that have accidents frequently. In these conditions there are roads which have sharp turns and as a result the driver has no visibility of the vehicles in the opposite lane. These are the places where everyone needs to be careful and intelligent enough. This problem is to inform the driver about the problem causing the object in the opposite direction. This can be achieved by installing an ultrasonic sensor on one side of the road before the curve, and positioning an LED light and buzzer on the opposite side after the curve.[1]

Design and Implementation of Accident Prevention with Alert Messages and Motion Sensors for Mountain Road Safety Design and Implementation of Accident Prevention with Alert Messages and Motion Sensors for Mountain Road Safety B Prasanth, S Aravindh, P Arun Dal ash, A Imran, S Sri Gowtham 2024 First International Conference on Electronics, Communication and Signal Processing (ICECSP), 1-5, 2024 The prevention of vehicle accidents in hilly places is a serious concern because of the particular difficulties presented by the topography and terrain. Drivers are faced with numerous challenges in hilly areas, such as steep grades, tight curves, small roads, and erratic weather, all of which raise the

possibility of collisions. To reduce these dangers and improve road safety in hilly areas, this abstract examines several technologies and tactics. In this paper the prevention system that harnesses motion sensor technology to enhance road safety, particularly in challenging environments like remote or mountainous areas. The system detects sudden changes in vehicle motion indicative of potential accidents and promptly alerts nearby hospitals via real-time communication channels. By providing vital accident information to hospitals, such as location and severity, the system enables swift and well-prepared emergency responses. Through simulations and field tests, the efficacy of the system is validated, highlighting its potential to significantly reduce accident rates and mitigate the impact of road incidents. This innovative solution not only facilitates real time accident detection but also streamlines emergency response efforts, ultimately improving overall road safety and saving lives. Moreover, the system's integration with existing intelligent transportation systems enhances its scalability and effectiveness. [2]

Revolutionizing Safety: An Arduino-IoT System for Accident Prevention based on Innovative Practices 2024 4th International Conference on Innovative Practices in Technology and Management (ICIPTM), 1-6, 2024 This study offers a practical plan to reduce the large number of traffic accidents that occur in India's hilly terrain, especially around hairpin curves where visibility is low and blind turns are prevalent. The suggested remedy makes use of an innovative Arduino integrated ultrasonic sensor accident prevention system. The device is made to alert drivers of approaching cars at these curves using a buzzer and LED signals. This crucial intervention successfully improves overall traffic safety measures because it is specifically designed to operate in low visibility situations and high-risk areas. [3]

Curve Monitoring and Alert System for Smart Transportation Curve Monitoring and Alert System for Smart Transportation Yuvaraj Natarajan, Shrinithi Viswanathan, Sandhiya Jayarathinam Vikas Balasubramaniam 2024 International Conference on Cognitive Robotics and Intelligent Systems (ICC-ROBINS), 670-675, 2024 The proposed IoT-based Smart Curve Monitoring and Alert System is designed to improve road safety through the fusion of embedded systems, machine learning and edge computing technologies. The proposed system is primarily powered by ESP32 microcontroller, continuously gathers data from an array of sensors, including accelerometers, gyroscopes and a potentiometer to set the speed limit. This collected data is then subjected to analysis by a Convolutional Neural Network (CNN) model, which has been trained to recognize driving patterns, especially when navigating curves. Here, CNN classifies the vehicle's behavior as safe and risky, and if a risky behavior is identified, it triggers an alert and dispatches relevant data to a Node MCU device. The Node MCU Communication tasks. It receives the alert from the ESP32, validates the vehicle's speed against the preset limit, and, if necessary, activates a GSM module to send an immediate notification to designated guardian. [4]

Collision avoidance for autonomous vehicles using reachability-based trajectory planning in highway driving Collision avoidance for autonomous vehicles using reachability-based trajectory planning in highway driving Hadi Raees , Alireza Khosravi, Pouria Sarhadi Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 09544070231222053, 2024 As vehicle applications have evolved to a more intelligent and self-driving stage, autonomous vehicles have attracted more attention in recent years. This paper proposes a trajectory planner that considers feasibility, safety and passenger acceptance. This will ensure autonomous vehicles satisfy the constraints of the traffic environment, driving ability, and comfort drivers experience during collision avoidance. This paper deals with planning collision-free trajectories for autonomous vehicles on highways. The problem is formulated using reachability-based planning via zonotope. According to the vehicle dynamics model, the trajectory feasibility is determined by the vehicle motion feasibility set. The next step is to apply safety constraints to the base planner by collision avoidance checking. Given that this planner uses a receding horizon strategy, it selects a safe parameter in each planning iteration. At each stage of planning, the set of reachable vehicles should not intersect with any obstacles. Since braking cannot prevent a collision, this approach consists of lane changing and overtaking maneuvers to avoid collisions. Finally, knowledge from the safety of the intended functionality (SOTIF) standard is utilized to verify the algorithm performance. [5]

Smart Roads: U-Turn Accident Prevention System When discussing statis tics of everyday road accidents in India, a very large contributing factor is accidents in hilly areas due to hairpin bends. These blind turns are highly dangerous and may more often than not result in fatal accidents. The low visibility results in the driver being extremely vulnerable to head-on collisions. Coming up with a preventive measure to this perilous situation is the prime focus of this paper. The proposed system in this paper is to, warn drivers of other vehicles at hairpin curves to avoid accidents involving human lives. This system is designed to allow residents and tourists to drive safely by warning them of blind corners and U-turns and reducing the possibility of accidents. [6]

Beyond the Current Curve: A Novel Curve Warning System Considering Subsequent Curve Speed Limits This work presents a novel curve warning system that addresses the existing Advanced Driver-Assistance Systems (ADAS) limitations. While current ADAS offer curve warnings, they often lack the consideration of subsequent curve's speed limit and distance, hindering optimal warning location calculations. Our proposed method leverages Google Maps path data and an existing curve detection system to extract curvature information. This information is then utilized to warn drivers about approaching curves at the safest possible location, taking into account the speed limit of the adjacent curve. Real-time experiments showcase the effectiveness of this system in providing timely and accurate warnings. Furthermore, we conduct a comparative analysis within the Carla simulation environment. [7]

Smart Vehicle Monitoring and Accident Detection System Smart Vehicle Monitoring and Accident Detection System Vedant Singh Bhagoti, Ayush Kumar Pandey, Arshad Iqbal, OV Gnana Swathika Smart Grids as Cyber Physical Systems: Smart Grids Paving the Way to Smart Cities 2, 163-184, 2024 There is a growing problem of loss of life from road accidents. According to reports from the WHO and the Indian Ministry of road transport, around 1.5 million lives are lost to road accidents every year. The major reason for loss of life is untimely help to the victims. There is a delay in the relay of accurate information about the accident spot to hospitals and police stations. Precious seconds are lost and due to this delay

life-saving help cannot be provided when crucial. The authors have devised a new strategy based on existing technology, to prevent this unnecessary loss of life. This paper discusses using Arduino Uncoupled with infrared and ultrasonic sensors to measure the speed of the oncoming vehicles closer to the accident spot. This inexpensive technology can also be deployed at blind spots on curvy mountain roads to detect over speeding and dangerous driving. The next part of the paper discusses using already present cameras to monitor vehicles live. Machine learning algorithms like open CV and CNN are used to detect accidents in case of a crash. As soon as the algorithms detect an accident, a message is sent to relevant authorities on their emergency number. This will be done within seconds of the crash occurrence. Hence the response time of vital services will be reduced. [8]

Ghat Hairpin Monitoring and Alert System Modern vehicles often come equipped with advanced collision avoidance systems, but these are often lacking in heavy-duty vehicles navigating treacherous roads with hairpin bends and blind turns. This paper proposes a novel Collision Avoidance System specifically designed to prevent head-on collisions at such locations. This proposed solution integrates a combination of sensors, including infrared (IR) and ultrasonic sensors, an ESP32 camera module for car detection, and an LM2596Converter. Real-time data processing is the heart of the system. An ESP8266 microcontroller chip analyzes sensor outputs, including the distance to oncoming vehicles considering 10 cm s on this proposed scale model, and transmits critical information to a React-based web interface. Drivers can visualize a dynamic graph on this interface, allowing them to proactively adjust their speeds and minimize collision risks. [9]

Design of Intelligent Speed Planning and Early Warning System for High-Speed Curved Road Design of Intelligent Speed Planning and Early Warning System for High-Speed Curved Road Li Ming, Wang Zhengyi, Wang Haoyu Proceedings of the 4th International Conference on Intelligent Information Processing, 24-28, 2019 According to an official US survey, traffic accidents at corners in highway accidents are eight times higher than in other road conditions [1]. Therefore, the warning of speed planning for corners is extremely important. This paper proposes a high-speed cornering intelligent speed planning early warning system for commercial vehicles with high-speed cornering that is prone to rollover accidents. Starting from the source of the driving, the system gives a hint to the driver before the cornering, and the slow throttle uses the inertial force to avoid the danger of brake failure caused by excessive braking on the brakes. At the same time, it can ensure that the vehicle leaves the corner at a safe speed to prevent the risk of rollover. Based on the lateral rollover model of the vehicle, the system calculates the critical safe speed of the curve, and combines with the longitudinal dynamics model to obtain the distance position for the slow-release throttle to slide. In this paper, Trucks in is used to build a motion simulation platform, and combined with MATLAB simulation, the simulation results show that the sliding distance increases with the increase of the initial velocity and decreases with the increase of the radius of the curve. [10]

III. PROPOSED APPROACH

A. Problem statement

Curved roads, especially hairpin bends, pose a significant risk to road users due to limited visibility and the inability to detect oncoming vehicles in time. This often leads to head-on collisions, especially when two vehicles approach the bend simultaneously from opposite directions. Despite the high accident rate in such areas, many curved roads lack effective real-time alert systems to warn drivers. To address this issue, this project proposes a traffic alert system using ultrasonic sensors and an Arduino Uno. The system detects vehicles approaching from both directions and activates a buzzer when simultaneous detection occurs, alerting drivers to slow down and proceed with caution. This solution aims to enhance road safety by providing timely warnings and preventing accidents on dangerous curves

BLOCK DIAGRAM

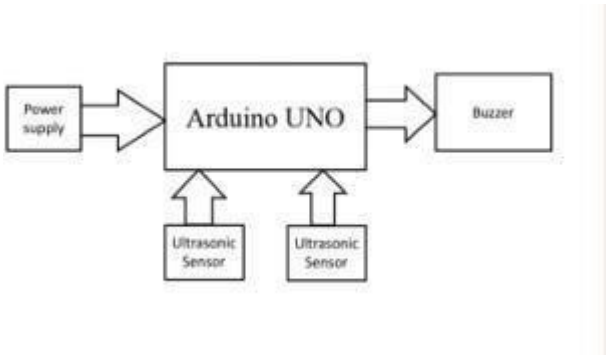

Figure: block diagram

The block diagram illustrates the core components and working of the traffic alert system designed to prevent accidents on curved roads, particularly hairpin bends.

1. Power Supply:

The power supply provides the necessary voltage to operate the Arduino UNO and the connected components. It may be a battery or an adapter, depending on the project setup.

2. Arduino UNO:

This is the central control unit of the system. It receives input signals from the ultrasonic sensors and processes them based on the programmed logic. If both sensors detect a vehicle at the same time, the Arduino triggers the output to alert the drivers.

3. Ultrasonic Sensors (2 Units):

These sensors are placed at both ends of the curve to detect incoming vehicles. They work by emitting ultrasonic waves and measuring the time it takes for the echo to return after hitting an object (vehicle).

One sensor monitors traffic from one direction.

The second sensor monitors from the opposite direction.

Their signals are sent to the Arduino UNO.

4. Buzzer:

The buzzer is the alert mechanism. When both ultrasonic sensors detect vehicles at the same time (i.e., two vehicles approaching the curve from opposite directions), the Arduino activates the buzzer to warn the drivers of a possible collision, prompting them to slow down.

B. Hardware

[1] **Arduino UNO**

The Arduino Uno is a widely used open-source microcontroller board based on the ATmega328P microcontroller, known for its versatility and ease of use in electronic projects and prototyping. It operates at 5V with a recommended input voltage of 7-12V and features 14 digital input/output pins (6 of which support PWM output), 6 analog input pins, and a 16 MHz clock speed. The board offers 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM. It can be programmed using the Arduino Integrated Development Environment (IDE) with C and C++ languages. The Arduino Uno connects to a computer via a USB cable for code uploading and communication, making it ideal for projects involving sensor interfacing, automation, robotics, and the Internet of Things (IoT). In the mini project, the Arduino Uno serves as the central control unit, facilitating the integration of various components and enabling smooth execution of project functionalities

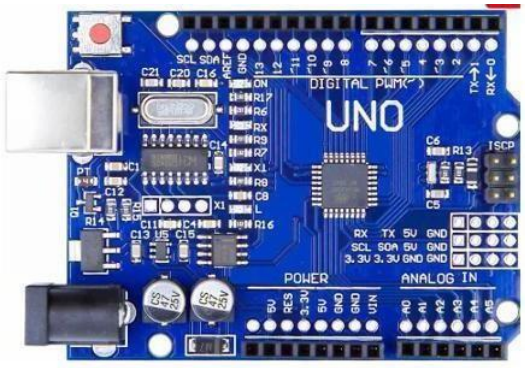

Figure: Arduino UNO

[2] Ultrasonic sensor

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target). In order to calculate the distance between the sensor and the object, the sensor measures the time it takes between the emission of the sound by the transmitter to its contact with the receiver. The formula for this calculation is D = ½ T x C (where D is the distance, T is the time, and C is the speed of sound 343 meters/second). Ultrasonic sensors are used primarily as proximity sensors. Ultrasonic sensors are also used in robotic obstacle detection systems, as well as manufacturing technology. In comparison to infrared (IR) sensors in proximity sensing applications, ultrasonic sensors are not as susceptible to interference of smoke, gas, and other airborne particles (though the physical components are still affected by variables such as heat).

Figure: Ultrasonic Sensors

[3] Buzzer

A buzzer is an audio signaling device widely used in electronic projects to generate sound alerts and provide auditory feedback. It operates by converting electrical signals into sound, often used in alarms, notification systems, timers, and embedded devices. There are primarily two types of buzzers: piezo and magnetic. The piezo buzzer uses the piezoelectric effect to produce sound and typically requires an oscillating signal, while the magnetic buzzer operates using an electromagnetic coil and can be driven with a simple DC voltage. Buzzers usually operate within a voltage range of 3V to 12V and consume low current, making them suitable for battery-powered systems. In microcontroller-based projects, such as those using the Arduino Uno, buzzers can be easily interfaced and controlled using digital signals or Pulse Width Modulation (PWM) to produce different tones. In the mini project, the buzzer is integrated to provide essential auditory alerts, contributing to the overall effectiveness and user interaction of the system. Its simplicity, reliability, and versatility make it a valuable component in various applications, especially where sound-based notifications are required.

Figure: Buzzer

C. Circuit Diagram

The circuit diagram represents the detailed wiring configuration of the components used in the traffic alert system. The project is based on the Arduino UNO R3 microcontroller board, which forms the core of the system. Below are the key components and their roles in the circuit:

1. Arduino UNO R3

Acts as the central processing unit.

It receives inputs from the ultrasonic sensors and controls the buzzer based on programmed logic.

2. Ultrasonic Sensors (2 units - HC-SR04)

Two ultrasonic sensors are used, positioned on either side of the curved road (left and right).

These sensors are connected to the Arduino through four pins each: VCC, GND, Trig, and Echo. . VCC is connected to 5V on the Arduino.

GND is connected to the ground.

Trig and Echo are connected to designated digital I/pins on the Arduino to send and receive the ultrasonic pulses.

The sensors detect the presence of vehicles by calculating the time taken for the echo signal to return.

3. Buzzer

Connected to a digital output pin of the Arduino.

When both ultrasonic sensors detect vehicles simultaneously, the Arduino triggers the buzzer.

The buzzer then emits a sound to alert the drivers of possible oncoming traffic from the opposite direction.

4. Power Supply

The circuit is powered either through a battery or US power to the Arduino UNO board. Ensures all components receive the appropriate voltage levels.

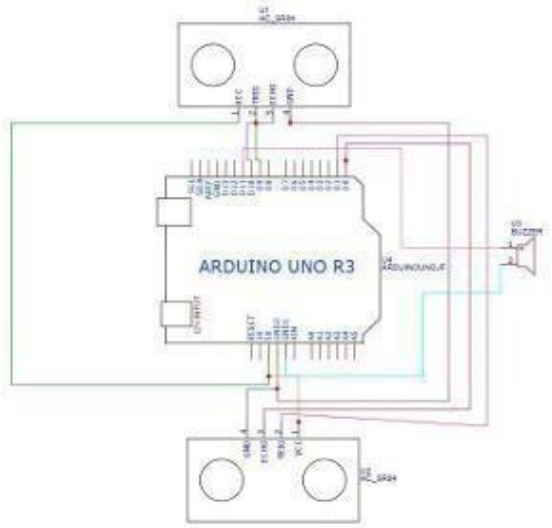

Figure: Circuit diagram

D.SOFTWARE

1)Arduino IDE

Arduino IDE offers full compatibility to any Arduino based software board. It makes it easy to write code and upload it to the board. Main features of Arduino are Sketch Editing Tools, Libraries, Serial Monitor, Programmer Functions, Burn Bootloader, Sketches Management, Sharing, and Auto Format

IV. EXPERIMENTAL RESULTS

The Traffic Alert System for Curved Roads project aimed to design and develop a system that detects vehicles approaching a curved road section and alerts drivers to potential hazards.

The system utilized dual ultrasonic sensors and a buzzer to provide real-time alerts. The project achieved successful detection of vehicles approaching the curved road section from both directions, providing timely alerts to drivers through the buzzer. The system's ability to detect vehicles and provide real-time alerts demonstrated its potential to enhance road safety by reducing the risk of accidents on curved roads. The project's results have significant implications for road safety, highlighting the potential for technology to prevent accidents and near-misses. The system's effectiveness in detecting vehicles and providing real-time alerts could be further enhanced by integrating it with other safety features, such as cameras or lidar sensors. Future work could focus on improving the range and accuracy of the ultrasonic sensors, as well as exploring the potential for integration with smart traffic management systems and autonomous vehicles. Overall, the Traffic Alert System for Curved Roads project demonstrated the potential of technology to enhance road safety and reduce the risk of accidents, with opportunities for further development and implementation in various applications.

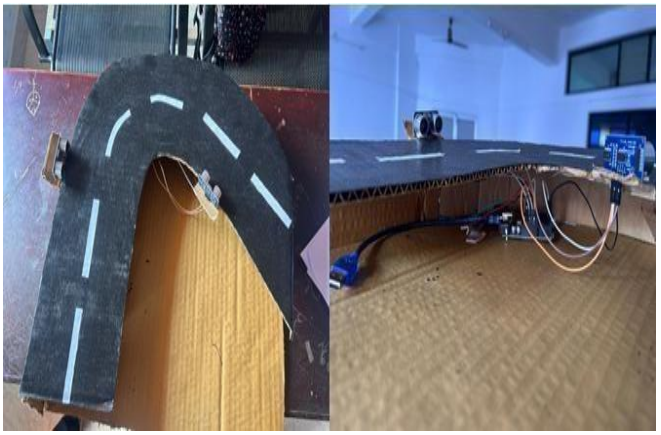

Figure: Traffic Alert System For Curved Roads

V. CONCLUSION AND FUTURE SCOPE

The Traffic Alert System proposed in this project offers a reliable, efficient, and innovative solution to improve road safety on curved roads, particularly on pocket roads. By leveraging advanced sensors and microcontrollers, the system detects approaching vehicles and alerts drivers of potential hazards, providing them with critical seconds to react and avoid potential collisions. The successful implementation of the Traffic Alert System can have a significant impact on road safety, reducing the number of accidents and saving countless lives. The system's simplicity, low cost, and ease of implementation make it an attractive solution for addressing the complex issue of road safety on curved roads. Furthermore, the Traffic Alert System can be integrated with existing traffic management systems, enhancing their functionality and effectiveness. The system's adaptability and scalability also make it suitable for deployment on various types of roads, from rural to urban areas. In conclusion, the

Traffic Alert System proposed in this project has the potential to revolutionize road safety on curved roads. Its innovative design, ease of implementation, and scalability make it an attractive solution for addressing the pressing issue of road safety. By adopting this system, we can create safer roads, reduce accidents, and save lives.

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INTERACTIVE NAVIGATION SYSTEM

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Abstract : **The project presents an innovative indoor navigation system designed for institutions, buildings, and malls similar to Google Maps. Utilizing a Raspberry Pi, LEDs, and pre-recorded voiceovers, the system provides users with clear directions and visual indicators to facilitate navigation. The system eliminates the need for GPS and sensors, reducing complexity and cost. With its user- friendly interface and assistive technology potential, this system offers a practical solution for indoor wayfinding. It features an interactive interface where users press a labeled switch corresponding to a specific location. Upon activation, a Raspberry Pi processes the input, triggering the corresponding LED on a root map board to blink ,and indicating the destination. Simultaneously, a pre-recorded voice instruction plays through a speaker, providing precise, turn-by-turn directions such as "turn left in 10 meters." All locations and voice instructions are pre- recorded and stored on an SD card, ensuring quick and accurate responses. The combination of LED-based visual signaling and audio assistance makes navigation intuitive and effortless for all. The system's components—including push-button switches, LEDs, and the Rasp berry Pi—are securely mounted on Hylum sheets, ensuring structural durability and long-term usability. The well-structured design prioritizes easy accessibility and user friendly operation, making it a reliable, efficient, and inclusive indoor navigation solution for various users.**

Index Terms— **GPIO , Voice Navigation, Audio Assistance, Indoor Navigation**

I. INTRODUCTION

The interactive navigation system is designed to guide users seamlessly through institutions, buildings, and malls, providing an experience similar to Google Maps. It offers both visual and audio feedback to help users identify and navigate to specific locations with ease. When a user presses a switch labeled with a particular location, the corresponding LED on the root map board blinks, visually indicating the destination. Simultaneously, a pre-recorded voice direction plays through a speaker, giving turn-by turn instructions such as "turn left in 10 meters." This ensures that users receive clear and precise navigation assistance. All locations are predefined, and voice guidance is recorded and stored on an SD card. A Raspberry Pi processes user inputs, triggers LED outputs, and plays the corresponding voice instructions. The system ensures inclusivity by catering to sighted users. While users can read the location labels and press the appropriate switches,and rely on voice feedback for guidance. This combination of visual and auditory cues makes navigation intuitive and effortless for everyone.

The components, including switches, LEDs, and the Raspberry Pi, are securely mounted on Hylum sheets for long- lasting performance. The structured design ensures easy accessibility and user-friendly operation. This navigation system provides a reliable, efficient, and accessible solution for indoor navigation, making it a valuable tool for a wide range of users.

II. PREVIOUS WORKS

An Intelligent Home Navigation System (IHNS) designed to assist elderly and physically challenged individuals in navigating their homes independently [1]. The system comprises a wheelchair, voice module, and navigation module, allowing users to move around their homes using voice commands. The IHNS addresses common challenges faced by the elderly and physically challenged, such as forgetting room locations and struggling to maneuver wheelchairs without external aid. The system operates by detecting the user's voice through a voice capture module, which is then compared to predefined voices loaded into the system. Based on the received voice, the destination is automatically understood, and the wheelchair moves along a predefined route. The IHNS also features obstacle avoidance technology, enabling the wheelchair to navigate automatically from one point to another within the home, even if the user is unable to provide clear voice commands.

To improve the robustness and reliability of multi-sensor navigation and reducethe uncertainties and complexity of sensor management in challenging environment, a resilient interactive sensor-independent-update (ISIU) method is proposed [2]. Inspired by the interactive cooperation theory, the contributions can be divided into two aspects. Firstly the priority of trust of navigation sensors is introduced into the information fusion in the form of transition probability matrix defined by Markov chain. Secondly every observable sensor is integrated with the propagated system in an elemental filter with sensor-independent-update structure.The overall estimation is determined by the weighted sum of average from every filter estimate. This weight of every model is dynamic updated by the prior transition

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The same independent structure is also applied to adopt new available sensor to realize plug-and- play navigation. The kinematic vehicle experiment in sub- urban and urban canyon environment verified the superiority of the proposed method. The ISIU method shows better accuracy and reliability compared to classical Kalman filters. The introduction of priority of sensors and decoupled measurement update process make it robust and insensitive to sensor measurement noise and outliers. The interactive sensor- independent-update structure has the natural function of fault detection and exclusion without additional operations. The effect of dynamic sensor selection is achieved in this processing. The proposed ISIU method is pretty suitable for resilient navigation in challenging environments.

Nowadays, the Global Positioning System (GPS) is used in outdoor environments as a navigation system, but there is still a need for an indoor navigation system [3]. Thus, this paper describes a proposed application that uses the augmented reality (AR) navigation system and creates a virtual character as guidance in a real-world view. The focus is on how the user can follow a virtual character to reach the desired indoor destination. The proposed method supports indoor and outdoor environments using a computer vision system to identify places. The application uses AR to render points of interest and navigation paths in the camera view. It has been found that AR provides aunique user interface for mobile applications that create human-computer interaction (HCI); therefore, smartphones are starting to embrace this HCI. The merge of AR, computer vision, and navigation technology will provide opportunities to adopt and develop new felids to create a new user experience. Navigation has been integrated with AR to enhance navigation usage. Besides that, adding a virtual character improved the user experience. As a result of using the proposed application, users reached their destinations interactively and enjoyably.

An environment map-free navigation algorithm for an indoor autonomous mobile robot using RF wireless sensor networks [4]. The algorithm enables the robot to navigate autonomously without a map by acquiring information from pre-set radio emission sensors deployed in the indoor environment. The robot's pose is determined by measuring the distance from one sensor node to another using the triangular localization method. The proposed algorithm is conceptually simple and easy to implement. Simulation and experimental results demonstrate that good localization can be achieved using this method, making it a promising solution for indoor navigation of autonomous mobile robots.

The system utilizes Augmented Reality (AR) technology via a mobile app, enabling real-time interaction with the environment [5]. Integrating AR with indoor mapping information provides a visual overlay that enhances navigation, making it more intuitive and engaging. It integrates a map-based interface with dynamic updates to reflect real-time changes in the environment. Evaluation results demonstrate high accuracy in location tracking and improved navigation efficiency compared to conventional methods. Users can enter their destination and receive turn-by- turn directions displayed through their smartphone's camera, delivering a distinctive and interactive navigation experience.

The development of this system addressed the need for more accurate and accessible navigation solutions in indoor settings, such as large buildings, malls, and airports, promising to enhance user experience and streamline wayfinding tasks. Future advancements in AR and mobile technology are expected to further refine and expand the capabilities of indoor navigation systems, making them even more effective and seamless.

Indoor navigation systems help provide route guidance in indoor environments, especially for large and complex spaces [6]. The development of indoor navigation systems includes several components, namely generating the indoor map to be used as the basis of the navigation system, mapping points of interest (POI), indoor positioning to locate the user's current position and route guidance for providing instructions to guide the user to his/her desired destination. When the indoor space gets larger or more complicated, the conventional manual processes of map creation and POI mapping become tedious and prone to errors. A semi-automated indoor navigation system framework is proposed to solve the mentioned issues. The proposed framework replaces tasks requiring manual operation with automated workflows requiring minimal human intervention. Indoor mapping using a stereo camera is used to reconstruct the 3D model of the indoor environment. The generated 3D model eliminates the need to create the 3D map from the 2D f loorplan and is useful for environments with no floorplans readily available. POI mapping is performed using object detection and optical character recognition (OCR) methods. Eventually, a mobile application is developed which utilizes the 3D map, the POI, the OCR results with YOLO detection algorithm, the NavMesh walkable surfaces and a Pathfinding algorithm to provide path generation and navigation functionalities. Overall, the proposed framework speeds up the process of indoor mapping and navigation significantly as compared to conventional methods.

The study addresses the issue of ambiguity in indoor navigation systems that rely on verbal instructions. The researchers propose optimizing landmark allocation to improve navigation clarity [7]. They developed a methodology that selects the best landmarks to use, reducing ambiguity at complex decision points. This approach leverages computational geometric analysis, graph algorithms, and optimization formulation.The paper introduces an innovative wayfinding system featuring addressable LED strips mounted on the ground of an environment, controlled via conventional button interfaces and advanced voice interaction integrated with GPT-4 [8]. These LED strips provide visual cues to guide users to various rooms, enhancing navigation. We detail the hardware setup, including LEDs, controllers, and network infrastructure, along with the design of the user interfaces. The system's performance was evaluated through a user survey, which indicated a preference for the touch interface while also highlighting the potential of voice interaction. Our findings demonstrate the system's effectiveness in providing intuitive and flexible navigation assistance without requiring additional user hardware. The proposed approach, the Ground Guiding Assistant System (GGAS), is implemented and utilized daily in an 813 m2 office addressing 13 rooms at the Center for Tangible AI (ZEKI) in Berlin

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The rapid development of virtual reality hardware, virtual tours in galleries and museums are more and more popular in recent years [9]. However, users sometimes get lost in the virtual space and miss displaying items during free exploration of the virtual scene. Therefore, proper navigation assistance is very important to help the user finish the tour and concentrate on the exhibits. Embodied agent can help users explore the scene effectively with higher interactivity and enhance user presence, butit cannot ensure completeness of visiting. In this paper, we investigate the effect of embodied agent on providing navigation assistance in virtual environments. We focus on the motion control of the agent and experiment on different speed, stay time and interactivity settings of the agent. The result shows that interactive agent can enhance visiting completeness and user presence. With these findings, we provide important considerations for the design of embodied agent for navigation in virtual environments

An integrated indoor navigation system for ground vehicles, combining inertial sensors, LiDAR, WLAN, odometry, and floor maps [10]. The system automatically aligns and initializes its position indoors, without relying on GNSS. The researchers used an extended Kalman filter to estimate tilt angles and a sub image matching algorithm to determine initial position and heading. The system achieved submeter- level positioning accuracy in real-world tests. Similarly, an innovative navigation system has been designed to guide users seamlessly through institutions, buildings, and malls, offering an experience similar to Google Maps. It provides both visual and audio feedback to help users identify and navigate to specific locations with ease. When a user presses a switch labeled with a particular location, the corresponding LED on the root map board blinks, visually indicating the destination. Simultaneously, a pre-recorded voice direction plays through a speaker, giving turn-by-turn instructions such as “turn left in 10 meters”, ensuring clear and precise navigation assistance. All locations are predefined, and the voice guidance is recorded and stored on an SD card. A Raspberry Pi processes user inputs, triggers LED outputs, and plays the corresponding voice instructions.

The method of cooperative navigation is proposed in this study to solve the terrible results of the indoor pedestrian navigation due to GPS information unavailable andthe serious divergence of inertial navigation [11]. To improve the pedestrian navigation accuracy, the paper designs a cooperative pedestrian navigation system which is based on the distance restraint between the pedestrians and applies the information filter to get the navigation result. The experiment is designed to prove the effectiveness of co operative pedestrian navigation using the MIMU and UWB measurement equipment. The final results show that the interactive fusion of navigation information for each pedestrian is achieved and the divergence of the navigation results is restrained.

The proposed work explores the application of augmented reality (AR) for indoor navigation in emergency situations and large spaces using Unity NavMesh and the algorithm [12]. It provides real-time information about college class room and enhances the accessibility for people with disabilities. The proposed system utilizes Vuforia and Unity to construct the AR environment, integrating QR code scanning using the ZXING SDK, as well as the smart control of light bulbs, fans, and other appliances through ESP32, relay modules, and the Blynk API. Experimental results demonstrate the effectiveness of our approach in improving navigation accuracy and accessibility for users. Furthermore, the system’s real-time updates, user-friendly interface, and remote appliance control offer a versatile solution for various indoor environments. The proposed work presents a detailed explanation of the literature review, the operating architecture, discusses its social impact, limitations, and future scope, highlighting its potential to revolutionize indoor navigation and accessibility for all.

III. PROPOSED APPROACH

A. BLOCK DIAGRAM:

The development of this navigation system follows a structured approach, inte grating both hardware and software components for efficient and accessible indoor navigation. The system is built using a Raspberry Pi 3B+, which serves as the central processing unit to control input and output functions. In figure 1,The hardware components include 20 push buttons mounted on Board 1, which users press to select a specific location, and 10 LEDs on Board 2 that blink to indicate the chosen destination. These LEDs are controlled by an independent time delay circuit, ensuring precise blinking duration. A speaker is connected to the Raspberry Pi to provide pre recorded voice guidance, and all components are securely mounted on durable Hylum sheets for long-lasting performance.

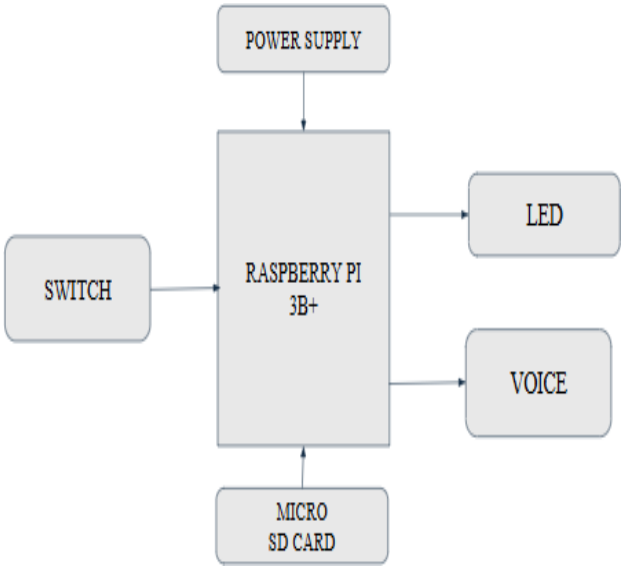

Figure 1 : Block Diagram of the system

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The software implementation involves storing pre-recorded voice messages on an SD card, linking each message to a specific push button. When a button is pressed, the Raspberry Pi detects the input and plays the corresponding voice direction, providing turn-by-turn navigation instructions. Simultaneously, the system triggers the appropriate LED on Board 2 to visually indicate the selected destination. The users in understanding location labels and navigating the system independently.

In Figure 1, it operates by allowing the user to press a switch labeled with a specific location. The Raspberry Pi then processes the input and activates the corresponding LED on the root map while playing a pre-recorded voice message through the speaker. The LED blinks for a predefined duration, controlled by a separate time delay circuit, ensuring clear visibility. This combination of audio and visual feedback ensures accurate and effective navigation. Designed for accessibility, the system accommodates the users. They can read location labels and manually select their destination,users rely on voice guidance for navigation.

The system undergoes rigorous testing to ensure accurate responses and seamless interaction between hardware and software components. By integrating LED cues, pre-recorded voice navigation, and accessibility features, this system provides a reliable, cost-effective, and user-friendly indoor navigation solution for institutions, buildings, and malls.

B. CIRCUIT DIAGRAM

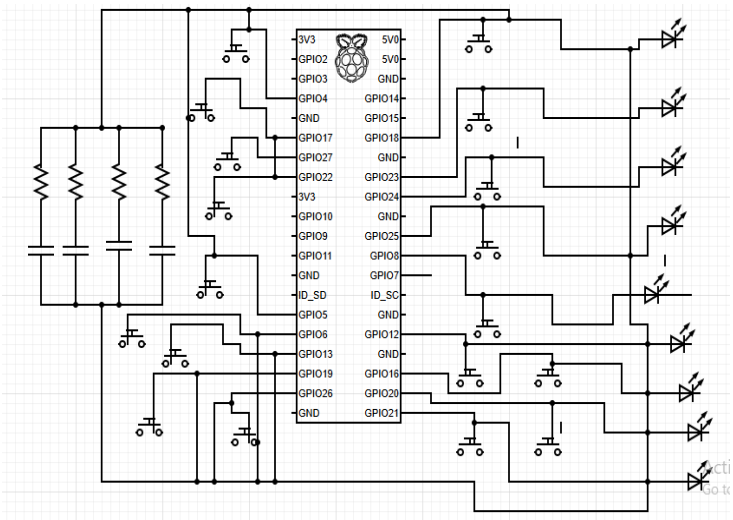

Figure 2 : Circuit Diagram of the system

The circuit diagram represents an innovative navigation system is system that uses a Rasp berry Pi to process user input from switches, control LED indicators, and play pre recorded voice directions stored on an SD card. The switches, when pressed, activate corresponding GPIO pins, lighting up the LEDs to indicate the selected location. Simultaneously, the Raspberry Pi plays voice guidance through speakers, providing turn-by- turn directions such as ”turn left in 10 meters.” Making the system usable for sighted individuals.

The LEDs, swithes and SD cards work together seamlessly, providing an efficient and accessible navigation experience in indoor spaces like buildings, institutions, and malls. In summary: 3V is used for the LEDs with current limiting resistors, ensuring safe operation and 5V powers the Raspberry Pi and other components that require a higher voltage, in the figure 2.

The design enables users to navigate complex indoor spaces with ease, reducing the risk of getting lost or disoriented. The voice guidance feature provides an additional layer of accessibility, allowing users to focus on their surroundings while receiving clear and concise directions. Overall, this innovative navigation system has the potential to revolutionize the way people navigate indoor spaces, providing a safe, efficient, and accessible experience for all users. In figure 2,the system’s compact design and low power consumption make it an ideal solution for installation in a variety of indoor locations, including shopping malls, airports, and public buildings. The use of a Raspberry Pi as the processing unit also makes the system highly customizable, allowing developers to easily modify and update the system’s software to meet specific needs. Additionally, the system’s modular design enables easy maintenance and repair, reducing downtime and ensuring that the system remains operational at all times.

A. COMPONENTS USED

1) Raspberry Pi

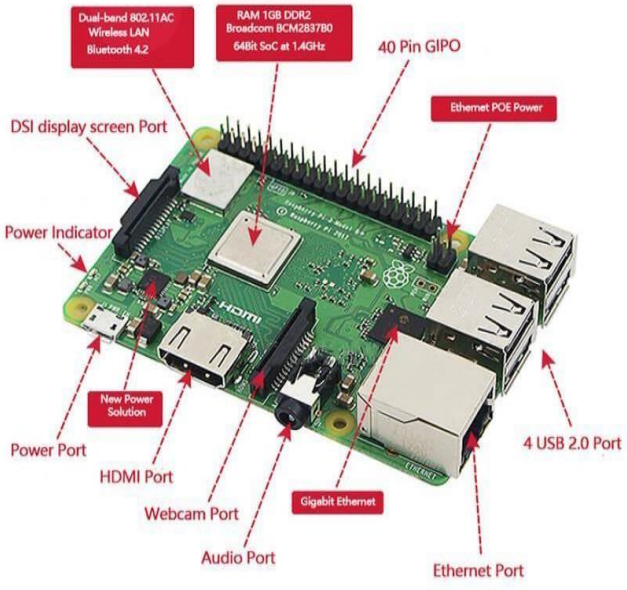

Figure 3 : Raspberry pi 3B+

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The Raspberry Pi 3ModelB+isapowerfulandfeature-rich single-board computer designed to promote teaching and learning of computer science, programming, and robotics. It boasts a 1.4GHz quad-core Cortex-A53 processor, which provides a significant boost in performance compared to its predecessors. The device also features 1GB of RAM, built-in Wi-Fi and Bluetooth, and a Gigabit Ethernet port, making it an ideal platform for a wide range of projects. Additionally, the Raspberry Pi 3 Model B+ supports Power over Ethernet (PoE) and has a range of other interfaces, including HDMI, USB, and GPIO. With its impressive specifications, versatility, and affordability, the Raspberry Pi 3 Model B+ is an excellent choice for anyone looking to build a low-cost, high- performance computer or IoT device.

2) Speaker

Figure 4 : Speaker

A speaker is an electronic device that converts electrical signals into sound waves, producing high-quality audio for music, movies, and other applications. Speakers come in various shapes, sizes, and types, including bookshelf speakers, floor-standing speakers, and portable Bluetooth speakers. They typically consist of a driver, crossover network, and enclosure, working together to produce clear and balanced sound. Modern speakers often feature advanced technologies, such as wireless connectivity, voice assistants, and waterproof designs. Some speakers also support multi-room audio, allowing users to stream music to multiple rooms or areas. With their ability to enhance audio experiences, speakers have become an essential component of home entertainment systems, public address systems, and personal audio devices. Additionally, speakers are widely used in various industries, including music, film, and live events, where high-quality sound is crucial.

3) Switch

Figure 5 : Switch

A push button switch is a type of electrical switch that is activated by pressing a button or lever, allowing users to control the flow of electrical current. These switches are commonly used in a wide range of applications, including industrial control systems, appliances, and electronic devices. Push button switches come in various types, including momentary, latching, and non-latching, each with its own unique operating characteristics. They are typically designed with a spring-loaded mechanism that returns the button to its original position after it is released. Push button switches are often used to provide a simple and intuitive way to turn devices on and off, or to trigger specific actions or functions. Some push button switches also feature illumination, such as LEDs, to indicate their status or provide visual feedback.

Additionally, push button switches are available in various sizes, shapes, and materials, making them suitable for use in a wide range of environments and applications. Push button switches are advantageous due to their ease of use, durability, versatility, and safety features. They offer a simple, intuitive way to control circuits, and are often found in various applications, from consumer electronics to heavy machinery.

4) SD CARD

Figure 6 : SD Card

A Secure Digital (SD) card is a type of non-volatile memory card used to store data, such as photos, videos, and files, in devices like cameras, smartphones, and tablets. SD cards are available in various capacities, ranging from a few gigabytes to several terabytes, allowing users to store large amounts of data. They come in different classes, including Class 2, Class 4, Class 6, and Class 10, which indicate their minimum write speed. SD cards also have different types, such as microSD, miniSD, and SDHC/SDXC, which are designed for specific devices and applications. SD cards are known for their high storage capacity, compact size, and low power consumption, making them a popular choice for mobile devices. They are also relatively inexpensive and easy to use, with a simple plug-and-play interface. Overall, SD cards provide a convenient and reliable way to expand the storage capacity of devices and transfer data between them.

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5) HDMICable

Fgure 7 : HDMI Cable

An HDMI (High-Definition Multimedia Interface) cable is a type of digital video interface used to connect devices such as TVs, computers, gaming consoles, and projectors. HDMI cables transmit uncompressed digital video and audio signals, providing high-definition picture and sound quality. They are designed to carry a wide range of signals, including video resolutions up to 4K (3840 x 2160 pixels), audio formats like Dolby TrueHD and DTS-HD Master Audio, and control signals for device communication. HDMI cables come in various lengths, ranging from a few feet to over 100 feet, and are available in different versions, including HDMI 1.4, 2.0, and 2.1. The latest HDMI 2.1 version supports even higher resolutions, faster refresh rates, and enhanced audio capabilities. HDMI cables are also hot-swappable, meaning they can be connected or disconnected without powering off the devices. Overall, HDMI cables have become the standard for connecting modern digital devices, offering a convenient and high-quality way to transmit audio and video signals.

6) CARDREADER

Figure 8 : Cardreader

A card reader is an electronic device used to read data from various types of cards, such as memory cards, smart cards, and credit cards. Card readers come in different types, including USB card readers, built-in card readers in laptops and desktops, and standalone card readers. They use various interfaces, such as USB, PCI, or PCMCIA, to connect to computers or other devices. Card readers can read data from different types of memory cards, including SD, microSD, CF, and MS. Some card readers also support additional features, such as card writing, card formatting, and encryption.Overall, card readers provide a convenient and efficient way to accessand transfer data from various types of cards to computers and other devices

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7) LED

Figure 9 : LED

LED stands for Light Emitting Diode. It is a semiconductor device that emits light. LEDs are energy-efficient and use less power. They come in different colors like red, green, blue, and white. LEDs are used in various applications like lighting, displays, and indicators. They have a long lifespan and can last up to 50,000 hours. LEDs are also environmentally friendly and free of toxic chemicals like mercury.

8) Rootmap Board

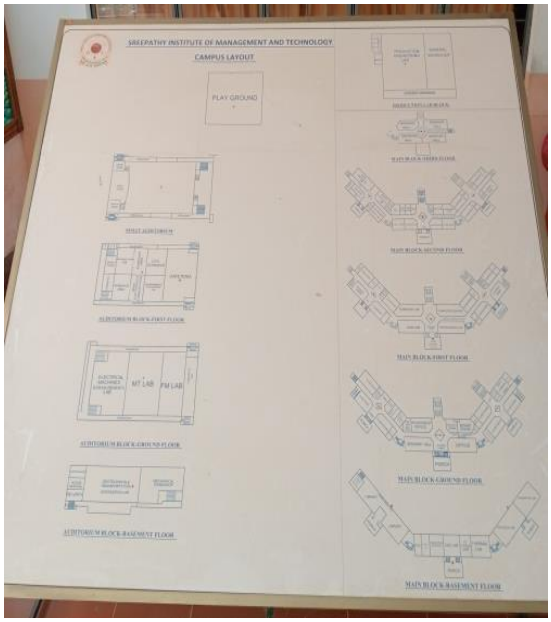

Figure 10 : Rootmap Board

The Root Map Board is an innovative tactile navigation system designed to facilitate easy navigation through institutions, buildings, and malls. Similar to Google Maps, it provides turn-by-turn directions and visual cues to guide users. The system features a board with fixed LED lights and location labels. To provide directions, the corresponding LED light blinks to indicate the destination, offering a clear and intuitive guide.

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B. SOFTWARE USED

- *Visual Studio Code*

Visual Studio is a robust integrated development environment (IDE) developed by Microsoft, designed to assist developers in building, testing, and deploying applications. It supports a wide range of programming languages such as C++, C, Visual Basic, JavaScript, Python, and more, making it highly versatile for different types of projects. Whether you're building desktop, web, mobile, or cloud-based applications, Visual Studio offers a unified platform to handle all stages of the development lifecycle. It is particularly popular for Windows development but also includes features for cross- platform development.

One of the main features of Visual Studio is its powerful code editor, which includes features like IntelliSense for code completion, syntax highlighting, and error detection. These features help developers write clean, error-free code faster by offering real-time suggestions and highlighting potential issues in the code. Requires manual setup for debuggers, compilers and profilers

Visual Studio Code, or just VS Code, is a free program made by Microsoft that lets you write and work on code easily. It's great for building websites and applications, and it supports a bunch of programming languages like JavaScript, TypeScript, and Node .js React is a popular JavaScript library developed by Facebook for building user interfaces. The Visual Studio Code editor supports React.js IntelliSense and code navigation out of the box. The integrated *debugging tools* are another strength, allowing developers to quickly identify and resolve bugs with advanced features like breakpoints, call stacks, and variable inspection.

- *Algorithm*

1. Import necessary libraries (RPi.GPIO, Pygame). RPi.GPIO is used to read input from buttons and control LEDs. pygame is used to play sound files when a button is pressed. Both libraries are essential for your Raspberry Pi navigation system because they allow hardware interaction (buttons, LEDs) and audio output (voice guidance)

2. Initialize GPIO pins as inputs with pull-up resistors. This means setting up the GPIO (General Purpose Input/Output) pins of a Raspberry Pi to receive input (like detecting a button press) while using an internal pull-up resistor to keep the pin in a default HIGH state when no button is pressed.

3. Define audio files and corresponding GPIO pin mapping. This means assigning specific audio files to specific GPIO pins on the Raspberry Pi. When a button connected to a GPIO pin is pressed, the corresponding audio file will be played.

4. Initialize Pygame mixer for audio playback. This means settingupthePygamemixermodulesotheRaspberryPicanplayaud io f iles. The Pygame mixer is a part of the Pygame library that handles sound playback, including loading and playing audio files like MP3 or WAV.

5. Define function to play audio file. This means creating a custom function in Python that takes an audio file name as input and plays it using the Pygame mixer.

6. Attach event detection to each GPIO pin. This means setting up the Raspberry Pi to automatically detect button presses (or other input changes) on specific GPIO pins and trigger a function whenaneventoccurs. Instead of constantly checking the button state in a loop (polling), event detection allows the Raspberry Pi to detect changes instantly and efficiently.

7. Wait for button press (GPIO pin goes low). This means that the Raspberry Pi will pause execution until a button is pressed, which happens when the GPIO pin goes from HIGH to LOW. In the case, since pull up resistors are used, the GPIO pin is normally HIGH (1). When a button is pressed, the circuit is completed to ground (0V), making the pin LOW (0).

8. Get corresponding audio file path from mapping. This means retrieving the correct audio file name or path based on the GPIO pin that was activated (button pressed). Since, map GPIO pins to specific audio files using a dictionary, we can use the pin number as a key to get the corresponding audio file.

9. Play audio file using Pygame mixer. This means using the Pygame mixer module to load and play an audio file (e.g., MP3, WAV) on your Raspberry Pi. The Pygame mixer is a sound library that allows you to handle audio playback easily.

10. Repeat steps 7-9 until program exit. This meanstheprogramshouldcontinuously wait for button presses, get the correct audio file, and play it, in a loop, until the user stops the program (e.g., by pressing Ctrl + C). In the case, steps 7-9 refer to: Step 7: Wait for a button press (GPIO pin goes LOW). Step 8: Get the corresponding audio file from the mapping. Step 9: Play the audio file using Pygame mixer. These steps need to repeat indefinitely so that the Raspberry Pi keeps responding to button presses until the program is manually stopped.

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IV. RESULT AND DISCUSSION

- **Result**

The implemented navigation system successfully provides both visual and auditory guidance to users within an institution or commercial space. The system functions as follows:

1) User Interaction:- When a user presses a switch labeled with a location, the system responds immediately.- The corresponding LED blinks on the root map board, providing a clear visual indication of the selected destination.- Simultaneously, a pre-recorded voice direction plays through the speaker, guiding users with turn-by-turn instructions.

2) Navigation Accuracy:- The pre-recorded audio instructions provide precise and easily understandable guidance.- The LED indicators help sighted users quickly identify their desired locations.-The users access location information independently.

3) System Performance:- The Raspberry Pi efficiently processes input from the switches, controls the LED indicators, and plays the appropriate audio file.- The system operates with minimal latency, ensuring a smooth user experience.- The Hylum sheet mounting ensures durability and secure installation of components

- **Discussion**

1) Effectiveness of the System- The combination of LEDs and voice guidance provides a robust solution for navigation. The system mimics the functionality of Google Maps but in a localized, offline setting. Users can navigate efficiently without requiring a mobile application or GPS signals.

2) Accessibility and Inclusivity- They can identify locations and navigate independently.- The system caters to a wide range of users, including those unfamiliar with digital maps or technology.

3) Potential Improvements- Dynamic Path Guidance: Currently, the system provides static pre-recorded instructions. Implementing dynamic pathfinding with real-time distance calculation could enhance accuracy.- Multiple Language Support: Adding multilingual voice guidance could cater to diverse users.

4) Overall Impact This navigation system effectively bridges the gap for individuals who need indoor navigation assistance. It provides a cost-effective and user-friendly solution, making navigation intuitive and accessible for everyone.

V. CONCLUSION AND FUTURE SCOPE

- **CONCLUSION**

The navigation system is designed for universal accessibility, allowing individuals to navigate institutions, buildings, and malls with ease. Sighted users can read location labels and press the corresponding switch to receive visual (LED blinking) and audio (pre-recorded voice) guidance. The users can rely on the voice navigation feature, which provides step-by-step instructions without requiring visual input. It enhances accessibility by helping them navigate independently.

It offers an innovative and practical solution for addressing the growing challenge of wayfinding in complex indoor environments such as institutions, buildings, and malls. By utilizing accessible technologies like Raspberry Pi, LED indicators, and pre-recorded voiceovers, the system provides clear directions and visual indicators, guiding users efficiently without the need for costly GPS or sensors. This reduces both complexity and cost, making it an ideal solution for various applications. The system's user-friendly interface, combined with its assistive technology potential, ensures it is accessible to users of all ages and abilities, particularly benefiting those with disabilities.

Additionally, the system's cost-effectiveness and scalability make it suitable for both small and large spaces, offering an affordable and easily adaptable solution for wayfinding. By integrating real-time feedback, voice prompts, and visual cues, the system enhances the user experience and can even be expanded to integrate with other smart technologies, like emergency evacuation protocols or real-time updates. In conclusion, this system provides an inclusive, scalable, and efficient solution for indoor navigation, offering a practical and forward-thinking approach to modern wayfinding needs

FUTURE SCOPE

The future scope of this system is vast and promising, offering numerous benefits and significance. The system's benefits include improved accessibility, enhanced user experience, increased efficiency, and customization. Its significance lies in its potential to develop assistive technologies for individuals, automate processes in industrial settings, create interactive educational tools, and provide feedback in healthcare. In terms of marketing, the system can be targeted towards the healthcare industry, education sector, industrial automation, and assistive technology markets. Looking ahead, the system can be integrated with Artificial Intelligence (AI) to enhance its decision-making capabilities, connected to the Internet of Things (IoT).

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Potential applications include smart homes, industrial control systems, medical devices, and educational tools, making it a versatile and innovative solution for various industries. Furthermore, the system's modular design and use of Raspberry Pi enable easy customization and modification, allowing it to adapt to evolving needs and technologies. As the system continues to evolve, it is poised to make a significant impact in various fields, improving lives, increasing efficiency, and driving innovation.

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RAINSHIELD: Automatic Cloth Retrieval System

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Abstract—The RAINSHIELD: Automatic cloth Retrieval System is an innovative system designed to protect clothes from unexpected rain by automatically detecting precipitation and retracting a clothesdrying mechanism. This project integrates sensors, microcontrollers, and a motorized system to provide a hands-free solution for outdoor drying. A rain sensor detects the onset of rain and sends signals to a microcontroller, which then activates a motorized mechanism to retract the clothes into a sheltered area like a gateway mechanism. Once the rain stops, the system can be programmed to redeploy the clothes for drying. The system is energy-efficient, user-friendly, and can be implemented in households, apartments, and commercial bhalaundries. This project not only ensures convenience and protection for users but also prevents unnecessary re- washing due to rain exposure, ultimately saving time, water, and detergent. The automation enhances reliability, making it a practical addition to smart home solutions

KEYWORDS: Rain sensor ,Servo motor, Arduino UNO

I. INTRODUCTION

Today it is difficult to predict the changes in the season especially during the rainy season. In rainy season it's very rare that we can find sun rays to dry our clothes but how it possible to make our clothes to expose to sun rays as soon as it available. So there is need for human intervention who continuously monitors this. Keeping a person continuously watching for sun rays is too much stupidity as a waste of time. People often forget to lift the suspension of clothing during the day rain. For people who working, they don't have to worry about their clothes that have been dried outside. People often don't have time to manage their routine. This project develop for working couple, it is hard to find time to have laundry day where the cloth is dried through the whole day because the weather can change from sunny to rainy days. This projects use Arduino microcontroller and sensors to install all program that will give instructions to conduct this system properly and will automatically retrieve-out the clothes when it is the sunny day and oppositely retrieve-in the clothes when it is a rainy day. We decided to make an Automatic based project which protects clothes from being wet during without any human being, We chose this project as it is a basic problem in the region where it rains heavily. The proponents proposed a product to solve the problem of unexpected rain and have clothes hanging on outside by developing an automated dry rack(clothes line) that detects the rain and move clothes to a sheltered area.

II. PREVIOUS WORKS

Rain rate is the key parameter to calculate rain fade. The measurement of rain rate is in the unit of millimeter per hour while the rain fade is in the unit of decibels per kilometer. The rain rate is usually determined by using a device called the rain gauge but current industrial grade instruments for measuring the rain rate are too expensive and not affordable.. The rain gauge available in the market also lacks the use of IoT, making obtaining the data to be in manual mode and require frequent human interaction with it.[1]

Rain may be consistently and precisely detected using a variety of technologies and methods, including conductive, optical, capacitive, and auditory sensors. The flow study illustrates the procedures required to operate the coconut shell rain sensor. The coconut shell is used to characterize the rain sensor. When the rain sensor detects precipitation, the motor activates, and the surface water level is utilized to remove surplus runoff and rainfall water from the farmed land's surface. This allows rainwater to be stored for use in the circuit later on. If this is the case, it is used to gauge the quantity of water in the soil and is required to gauge the field's water level. The pump will start working, and the alarm will sound if there is an excess of water detected.[2]

The Water Rain Sensor with Alarm is a technology device that detects and alerts users when rainfall is present. It aims to provide an early warning system for potential dried clothes on a clothesline or flooding in a variety of locations, especially properties. This abstract highlights the Water Rain Sensor with Alarm's primary features and functionalities. The Water Rain Sensor detects the presence of rainwater using advanced sensor technologies. It has highprecision moisture sensors strategically located in places prone to water collection, such as roofs. These sensors constantly monitor the moisture levels in their surroundings and immediately sound an alarm if they detect an abnormal increase, showing the presence of rains.The alarm systems built into the Water Rain Sensor is an efficient way of informing consumers about dry clothes on a clothesline or flooding issues. When the rain sensors detect rainwater, the alarm is triggered, emitted a loud sound, and visual indicators are displayed to draw quick attention.[3]

A Laundry tasks are commonly performed as part of the daily routine, posing a challenge for individuals with time

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constraints, especially those engaged in busy daily schedules. This project endeavors to create an automated cloth hanger system that responds to weather changes, aiding users in managing laundty, particularly during rainy days.The DC motor's movement is guided by feedback signals from the sensors, detecting rain, low light levels, and high humidity[4]. Realtime rainfall monitoring is an important tool to be used for agriculture, water resource management, erosion, and energy production[5]. It also plays a key role in short-term weather forecasting, and prediction of wildfire risk, early warning about f looding risk, and triggering of landslides. The need for rainfall rate measurements isadditionally motivated by the significant role that precipitation has in climate change, both in terms of intensity and spatial and temporal distribution[5].

This System using IoT devices such as Node MCU and the several sensors like Soil Moisture, Soil Temperature, Humidity, and Rain drop detection sensor. The sensors are integrated to collect the different parameters of the field. The data are collected from the sensors can be used for the real-time monitoring of agriculture field without the presence of the Farmer in the field. This project may help to control the over water consumption of the soil and provide proper irrigation to increase the crop yields. It can also intimate the Farmer whether there is raining on the agriculture field. The farmers can control the motor and to monitor the field on anytime and at anywhere through the Mobile Application[6].

Traditional car wiper systems often operate at preset intervals or manual controls, leading to inefficiencies during varying weather conditions. The development of automatic rainsensing car wipers addresses this challenge by leveraging sensor technologies and automation to enhance safety and convenience for drivers. The problem lies in inefficient and inconvenient manual control of windshield wipers during varying weather conditions, particularly wiper systems that rely on preset intermittent settings or manual adjustments, which may not always match the intensity of the rainfall in real time.[7] This short communication paper aimed to design and implement a raindrop sensor to control the movement of the pond cover of aquaculture automatically using a microcontroller.The software used for programming the microcontroller was Arduino IDE.Determination of rain conditions obtained by direct experiment in the real rain conditions.In the construction of wireless vehicular communication networks, an innovative approach is proposed that incorporates additional multipath components to simulate the impact of raindrop scattering on the vehicle-to-vehicle (V2V) channel,thereby emulating the channel characteristics of vehicular environments under rainy conditions and an equalization strategy in OFDM-based systems is proposed at the receiver end to counteract channel distortion.Moreover, it only took microseconds to predict with high accuracy, surpassing the performance limitations of traditional sensing systems under adverse weather conditions. This breakthrough ensures that intelligent vehicles can rapidly and accurately adjust driving parameters even in complex weather conditions like rain to autonomous drive safely and reliably[8].

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A novel sensing principle for dendrometer (rain sensor) based on a resonant scan ning micromirror featuring high-speed detection in kHz range, accurate estimations of droplet rate, distribution, velocity, trajectory and two-dimensional (2D) shape. This high-speed ID MEMS scanner enables fast detection and compactness.

We introduce a calibration technique to convert temporal information of passing objects, recorded on a high-speed point detector, into spatial information. Measurements of freefalling steel balls achieve a maximum error of 5 percentage. Raindrop distribution and velocity measurements show good agreement with theoretical values.[10]

In the global regional and local regional tests, most of the accuracy and precision in rain intensity classification have reached more than 80 persontage .This technology makes full use of the rich observed information of CSCAT, realizes rain identification, and can also classify the rain intensity so as to further evaluate the degree of rain contamination of CSCAT products.[11]

When the rainy season the majority of people dry their clothes on the terrace of the house, this is done to Avoid drying clothes exposed to rain when the owner is left doing outdoor activities house. From the description of the problem above, the author found the idea to make a towing device clothesline that can work automatically. The tool uses an Arduino microcontroller The Uno is coupled with a rain sensor[12].

III. BLOCK DIAGRAM

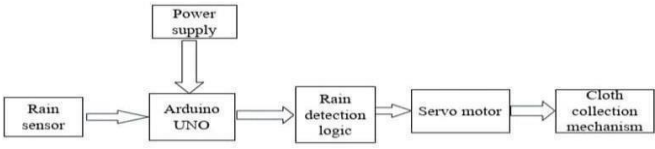

Figure 1: Block diagram of the system

The RAIN SHIELD: Automatic Cloth Retrieval System is designed to detect rainfall and automatically retract clothes to prevent them from getting wet. The system begins with a rain sensor, which senses water droplets and sends an electrical signal to the Arduino UNO. The power supply provides the necessary voltage to the Arduino and other components. Once the Arduino receives the signal from the rain sensor, it processes the input using pre-programmed rain detection logic to determine if it is actually raining. If rain is detected, the Arduino sends a control signal to the servo motor, which

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activates the cloth collection mechanism. The servo motor moves a retractable system by using a gate way mechanism. This automation ensures that clothes remain dry without requiring manual intervention, making it a convenient and efficient solution for rainy conditions.

IV. CIRCUIT DIAGRAM

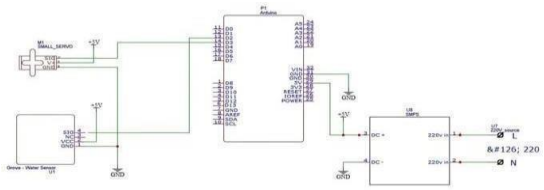

Figure 2: Circuit Diagram

This circuit diagram represents a RAIN SHIELD: Automatic Cloth Retrieval System, designed to protect clothes from getting wet during unexpected rainfall using an Arduino based automation mechanism. The system consists of an Arduino microcontroller, a rain Sensor, a servo motor, and a Switched Mode Power Supply (SMPS)for stable power delivery. The Grove Water Sensor is responsible for detecting rain by sensing moisture or water droplets. It is connected to the Arduino through its signal pin, and when it detects water, it sends a high signal to the Arduino, indicating rainfall. The Arduino processes this input and immediately triggers a servo motor, which is responsible for pulling the clothes under a shelter or rolling out a protective covering over them. The servo motor operates on a 5V power supply, ensuring smooth movement of the mechanism. The entire system is powered by an SMPS module, which converts 220V AC power from the mains to 5V DC, supplying the required power to all components. Under normal conditions, when no rain is detected, the clothes remain exposed for drying. However, as soon as the sensor detects rainfall, the system automatically activates the servo motor, ensuring that the clothes are quickly moved to a protected area. Once the rain stops, the system can be programmed to restore the clothes to their original drying position. This project is highly useful for households, smart laundry systems, and industrial applications, offering an efficient and automated solution for protecting clothes from unexpected rain without requiring human intervention.

V. COMPONENTS USED

A. Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the ATmega328P microcontroller, designed for beginners, hobbyists, and professionals in electronics and embedded systems. It is one of the most widely used Arduino boards due to its simplicity, affordability, and extensive community support. The Uno features 14 digital input/output (I/O) pins, out of which 6 support Pulse Width Modulation (PWM) output, and 6 analog input pins that can read varying voltage levels. It operates at 5V and has a 16 MHz quartz crystal to provide stable clock signals. The board includes an ICSP (In Circuit Serial Programming) header for direct programming of the microcontroller and a USB Type-B port that allows communication with a computer for programming the Arduino IDE. The Uno is compatible with a wide range of sensors, actuators, and shields, allowing users to expand its functionality for robotics, IoT, automation, and interactive projects. Its opensource hardware and software ecosystem ensures continuous improvements, making it a reliable choice for prototyping and learning embedded systems. It can be powered through a USB connection or an external power source (7-12V via a barrel jack or Vin pin). The ATmega16U2 chip on board handles USB-toserial communication, making it easy to interface with a computer without needing an external programmer.

Figure 3: Arduino Uno

B. RAIN SENSOR

A rain sensor module is an electronic device designed to detect rain and generate an electrical response for applications such as weather monitoring, irrigation control, and automation. It consists of two main components: a sensing pad and a control board. The sensing pad is a PCB with parallel conductive strips that detect rainwater by creating a conductive path, reducing electrical resistance. The control board processes this change and typically includes a comparator circuit, such as LM393, which provides both digital and analog outputs. The module usually operates on a low voltage, with an adjustable sensitivity feature. It has output pins for analog and digital signals, where the analog output provides variable voltage based on rain intensity, and the digital output gives a high or low signal depending on the threshold setting. This module is widely used in smart systems to automate responses based on rainfall detection.

Figure 4: Rain sensor

C. Servo motor

A servo motor is a rotary or linear actuator designed for precise control of position speed, and torque in various applications such as robotics, automation, and remote controlled vehicles. It consists of a motor, a control circuit, a position sensor (usually a potentiometer), and a feedback system. The motor receives a control signal, typically a Pulse

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Width Modulation (PWM) signal, which determines the angle of rotation. The position sensor continuously monitors the shaft position and sends feedback to the control circuit to adjust the motor's movement accurately. There are different types of servo motors, including AC servo motors, which are used in industrial automation due to their high efficiency and precision, and DC servo motors, which are commonly found in small-scale applications. Another category is stepper-based servo motors, which combine the precision of stepper motors with feedback control. Servo motors are widely used in robotic arms, CNC machines, aircraft control systems, and even prosthetic limbs, offering precise and efficient motion control in real-time applications.

Figure 5: Servo motor

D. Lithium ion batteries

A lithium-ion (Li-ion) battery is a rechargeable energy storage device known for its high energy density, long lifespan, and lightweight design, making it ideal for consumer electronics, electric vehicles, and renewable energy systems. It operates by moving lithium ions between the anode and cathode through an electrolyte during charging and discharging cycles. The anode, typically made of graphite, stores lithium ions when the battery is charged, while the cathode, composed of lithium metal oxides like Lithium Cobalt Oxide (LiCoO) or Lithium Iron Phosphate (LiFePO), releases lithium ions during discharge. The electrolyte, usually a lithium salt solution, enables ion transfer between the electrodes. Li-ion batteries have a high charge retention rate, minimal memory effect, and low self-discharge, making them highly efficient. However, they require proper thermal management, as excessive heat can lead to degradation or thermal runaway. Due to their advantages, Li-ion batteries are widely used in smartphones, laptops, electric vehicles, and energy storage solutions.

Figure 6: Lithium battery ions

VI. SOFTWARE USED

The Arduino IDE (Integrated Development Environment) is an open-source software platform used to write, compile, and simple and user-friendly interface that is ideal for both beginners and experienced developers working on embedded systems and electronics projects. The IDE allows users to write programs, known as sketches, using a simplified version of C/C++ programming language. These sketches can be compiled and uploaded to a connected Arduino board via a USB cable. The IDE features a built-in code editor with syntax highlighting, auto-indentation, and error detection, making it easier to write and debug code. Additionally, it includes a Serial Monitor and Plotter that help in viewing real-time data from sensors or other connected components, which is especially useful for testing and monitoring purposes. Users can choose their specific Arduino board and communication port from the Tools menu, and the software supports a wide range of boards including Arduino Uno, Nano, Mega, as well as third-party boards like ESP32 and ESP8266. The IDE also offers a Library Manager for adding external libraries to support various sensors, displays, and modules. With its cross platform compatibility on Windows, macOS, and Linux, and a web-based version for browser-based coding, the Arduino IDE remains one of the most popular platforms for rapid prototyping and learning in the world of embedded systems and IoT development

VII. EXPERIMENTAL RESULT

RAIN SHIELD: Automatic Cloth Retrieval System is designed to be helpful in household uses where wet cloths can be hung on system hangers so that whenever it rains, the system retrieves in the cloths to a shaded area like a gate way mechanism and wetting of cloth are been avoided. Like wise when rain stops the machine retrieves back the cloth to open atmosphere to continue drying. This includes conversion of electrical energy into mechanical energy.

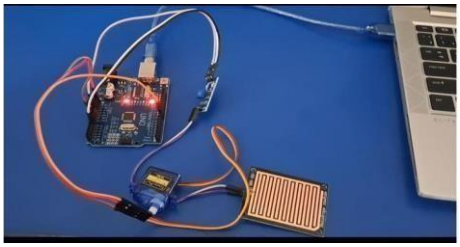

Figure 7: Hardware setup of the automatic cloth retrieval system

Figure 7 shows the hardware set up Rain shield automatic cloth retrieval system.A Microcontroller is used to convert signals into required form. When it starts raining, the rain drops fall on the rain sensor which consists of electrodes which are kept at certain small distance. When rain drops fall on these electrodes, the electrode gets connected and circuits gets completed, because of this action, signal is sent to the microcontroller which actuates the system and sends signal to the motor present in it and clothes will be retrived into the shades. Once the rain stops, the rain sensor gets dried up and circuit breaks then the microcontroller will check the for sunlight and if the conditions satisfy then the clothes are retrived out to the open atmosphere and drying of clothes is

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upload code to Arduino microcontroller boards. It provides a

continued. The project successfully automated the process of protecting clothes from unexpected rain, reducing human intervention

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Figure 8: Cloths left to dry

Figure 9: Retrieving cloths to sheltered area

Some key observations and discussions include: Effectiveness of the Rain Sensor:The sensor was highly responsive but required occasional recalibration to avoid false triggers due to high humidity or mist. Motor Performance: The selected motor had sufficient torque to retract the clothesline even when loaded with wet clothes, ensuring accesbility. Power Consumption: The system operated efficiently with low power consumption, making it viable for household use. Weatherproofing Challenges:The durability of the system in prolonged outdoor exposure needs further improvement,especially in ensuring waterproofing of electrical components. Future Improvements: Integrating a wind sensor and solar-powered operation could enhance the system's performance and energy efficiency.The implementation of the Rain Shield system demonstrated reliable automation of cloth retrieval in response to environmental conditions. During multiple test cycles, the system successfully detected rainfall using the sensor and retracted the clothesline with minimal delay, indicating accurate synchronization between sensing and motor control. The mechanical setup, including the pulley and drive system, exhibited stable performance under varying loads. User trials highlighted the convenience and practicality of the system in daily use, especially in unpredictable weather. However, observations also noted minor delays in response time during misty conditions, underlining the need for sensor calibration and filtering algorithms. Overall, the system met the core objectives of automation, protection of clothes, and efficient energy usage.

VIII. CONCLUSION

RAIN SHIELD: Automatic Cloth Retrieval System project presents an innovative and practical solution for protecting clothes from unexpected rain, offering convenience and efficiency in daily household activities. The system integrates a rain sensor with an automated mechanical setup, ensuring timely detection of rainfall and triggering the automatic collection of clothes. This eliminates the need for constant human supervision and prevents clothes from getting wet, especially during unpredictable weather conditions. This project addresses a common household issue where clothes left outside to dry get wet due to unexpected rain, especially when no one is present to collect them. By automating the cloth collection process, the system provides a convenient, timesaving, and efficient solution that helps prevent damage to clothes and reduces human intervention. It is particularly useful in regions with unpredictable weather conditions. This project successfully achieved its goal of protecting clothes from unexpected rain by automating the collection process. It accurately detects rainfall using a sensor and activates a motor to retract the clothesline or deploy a cover, minimizing manual effort. The system integrates hardware components effectively and responds reliably during testing. This practical and userfriendly solution offers convenience and demonstrates strong potential for real-life application and future upgrades. Overall, the project has a broad scope for technological advancement, commercial scaling, and environmental benefit.

IX. FUTURE SCOPE

This project has great potential for future development. Enhancements could include IoT integration for remote control, solar power for energy efficiency, and weather forecast connectivity for proactive operation. The design can be made more compact and durable, with the possibility of smart home integration using voice assistants. Additionally, the system could be scaled for commercial use in places like hostels or laundries, increasing its practical value and reach. Additionally, the system can be enhanced by incorporating artificial intelligence and machine learning algorithms to predict rain based on local weather data and automatically schedule drying times accordingly. To improve energy efficiency and environmental friendliness, the system could be powered using solar panels, reducing dependency on the electrical grid. Advanced rain sensing technologies, such as capacitive or optical sensors, can be employed to increase accuracy and reduce false detections. Incorporating humidity and temperature sensors would further refine the decisionmaking process for cloth drying. By replacing electric dryers with this automated system, users can adopt a more sustainable and energy-saving approach to drying clothes.

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MEDIGUARD 7X - A SMART, SECURE MEDICINE BOX FOR TIMELY MEDICATION

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Abstract

Medication management is a critical aspect of elderly and special-needs patient care, as missed or incorrect doses can lead to severe health complications. MediGuard 7X is a smart medication box designed to assist individuals in adhering to their prescribed medication schedules efficiently. The security features of this system ensure accurate and timely medicine intake. The core of the system is the Arduino Mega 2560, which controls multiple components, including an RTC module for time-based scheduling, RGB LED indicators for visual alerts, and a buzzer for audio notifications. A 16x2 LCD display provides real-time medication reminders. For enhanced security, an R307 Optical Fingerprint Scanner ensures only authorized users can access the medicine compartment. To further improve safety, the system features a servo-controlled solenoid lock, which automatically locks the medicine box after a designated time. MediGuard 7X is a cost-effective and user-friendly solution aimed at enhancing medication adherence while providing caregivers with real-time updates. By incorporating biometric security and automated alerts, this system significantly improves the safety and well-being of patients, making it an ideal solution for home healthcare and assisted living environments.

Keywords: Arduino Mega 2560, Fingerprint Scanner, RTC Module, Solenoid Lock, LCD Display

I. INTRODUCTION

MediGuard 7X is a comprehensive and intelligent medication management system developed with the primary goal of assisting elderly individuals and people with special needs in maintaining consistent adherence to their prescribed medication regimens. Medication non-compliance is a widespread issue, particularly among the aging population and patients with cognitive or physical impairments. Missing a dose or consuming the wrong medication at the wrong time can lead to a wide range of complications, from minor side effects to life-threatening health emergencies. With growing numbers of patients requiring daily medication and caregivers overwhelmed

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by responsibility, there is a pressing need for automated, secure, and user-friendly solutions. MediGuard 7X addresses this challenge by integrating modern embedded systems, biometric security, real-time monitoring, and intuitive user interfaces to create a reliable, affordable, and effective solution that not only reminds patients but also controls and verifies access to medication. This smart solution aims to minimize human error while maximizing patient independence and safety across varied domestic or institutional settings.

At the heart of MediGuard 7X lies the Arduino Mega 2560 microcontroller, selected for its ample I/O capabilities and robust performance. It serves as the brain of the system, orchestrating the operation of several peripheral modules and executing time-based decisions. An essential module integrated into the system is the DS3231 Real-Time Clock (RTC), which maintains precise timekeeping even during power outages thanks to its onboard battery backup. This RTC ensures that medication alerts are triggered exactly at the programmed times, avoiding errors caused by clock drift or reset. The system supports scheduling of multiple daily doses and associates each time slot with a particular medication compartment.

To alert users visually, MediGuard 7X uses RGB LEDs, where green indicates the active compartment containing the medication due to be taken, and red shows inactive sections. These visual cues provide immediate recognition, especially for users with limited literacy or cognitive ability. Each of the seven compartments in the medicine box is equipped with two RGB LEDs connected in parallel for better illumination, ensuring that the light is bright enough to draw attention, even in daylight. This design simplifies wiring by using a single data pin per compartment while maximizing user focus. Complementing the visual system, a buzzer is included to give audible alerts, helping those with visual impairments or those who may not notice the LED indicator. The buzzer pattern is designed to repeat if the dose is not taken, acting as a snooze system with recurring notifications, which mimics the reminder features in smartphones and smartwatches but tailored specifically for elderly patients.

To provide real-time feedback, instructions, and a friendly user interface, a 16x2 I2C LCD display module is mounted on the front panel of the device. This display shows personalized greetings, current time and date, and medication instructions such as "Take your morning medicine now" or "Please scan your fingerprint to open the box." The I2C communication protocol used by the LCD minimizes the number of GPIO pins needed, allowing more ports for other functionalities and reducing system complexity.

One of the standout features of MediGuard 7X is its secure access system. Unauthorized access to medicines—whether by children, confused patients, or others—is a genuine concern in households and care homes. To prevent misuse, the system employs an R307 Optical Fingerprint Sensor. This biometric scanner ensures that only the enrolled user (typically the patient or caregiver) can unlock the medicine compartment. The fingerprint authentication process is enabled only during the scheduled time slot, further preventing access at unintended hours. Upon successful fingerprint verification, the Arduino activates a high-torque MG996R servo motor to control the lid-opening mechanism. Simultaneously, a solenoid lock is disengaged, allowing the compartment to be opened only during the allotted 5-minute window. After this duration, the servo motor automatically returns the lid to the closed position, and the solenoid re-engages to lock the box. This timed locking mechanism ensures strict regulation of medication access and minimizes the risk of overdose or accidental intake.

In the event that the patient fails to authenticate or take the medication, the system continues to remind the user at five-minute intervals for a predetermined number of times. If still unattended, the system sends a text message notification to a registered caregiver or family member using a GSM module, alerting them of a missed dose. Likewise, once the fingerprint is successfully authenticated and the medicine is retrieved, a confirmation message is sent to the

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caregiver, providing peace of mind and real-time tracking. This remote notification feature strengthens the communication loop between patients and caregivers, even in geographically distant setups. It helps build trust between family members and medical staff while ensuring patient health outcomes are prioritized.

From a mechanical design perspective, MediGuard 7X features a large plastic box with a flip-top lid, internally divided into seven sections using plastic sheets. These sections are labeled to represent specific times of the day, such as "Before Breakfast," "After Breakfast," "Noon," "Afternoon," "Evening," "Before Dinner," and "After Dinner." This structure accommodates users who require frequent dosing throughout the day. The lid is shared across all sections but only opens at the correct time slot, ensuring proper medication delivery. Every element of the physical layout has been carefully considered to balance accessibility, visibility, and security. The device is powered using a standard 12V DC adapter through a barrel jack, with internal voltage regulation to support 5V and 3.3V modules safely. Power distribution is optimized to handle high-current devices like the servo motor and solenoid without voltage drops or overloading the Arduino's onboard regulator. Thoughtful wiring, current-limiting resistors for LEDs, and flyback protection for the solenoid circuit ensure long-term safety and durability.

MediGuard 7X is not only a technical solution but also a social one. Its primary goal is to increase medication compliance without requiring users to rely on mobile apps or smartphones, which many elderly individuals may find challenging. By combining automation with simplicity, the system empowers patients to manage their health independently, reducing the workload on caregivers and lowering the risk of medical emergencies due to missed doses. Furthermore, its cost-effective design—using widely available components and open-source platforms—makes it scalable and suitable for mass adoption, particularly in developing regions where access to healthcare technology is limited. The project reflects a deep understanding of the daily struggles of patients and caregivers, blending engineering with empathy. It not only addresses a common problem but also contributes to improving the quality of life for some of the most vulnerable members of society. In conclusion, MediGuard 7X is a robust, intelligent, and compassionate solution that represents a meaningful step forward in personal healthcare technology. By integrating biometric security, real-time alerts, user-friendly interfaces, and precise time-based control, it offers a smart and secure approach to medication management suitable for use in homes, clinics, and assisted living environments. Its adaptability and potential for customization make it future-proof and extendable for broader medical and wellness applications.

II. PREVIOUS WORKS

Timely medication is essential for the elderly, who often struggle with memory loss, chronic conditions, and limited physical mobility. Traditional pill boxes are prone to user error, leading to missed doses or incorrect medication intake, thereby increasing health complications. To tackle this, researchers have proposed a variety of smart medication dispensers, integrating modern technology such as microcontrollers, sensors, mobile apps, and IoT capabilities. In [1], a programmable medicine box was developed using an ESP8266 microcontroller with real-time clock support and buzzer alerts to ensure timely medication intake, especially for elderly individuals. Building upon the need for intelligent reminders, [2] introduced an IoT-integrated smart pillbox with face recognition and load cell support, offering controlled access and real-time monitoring of medicine intake through a Raspberry Pi-based setup. For cost-effective deployment, [3] proposed a 3D-printed Arduino-based medicine box controlled by a mobile application, making it suitable for both homes and emergency healthcare settings. Papers such as [4] and [5] emphasized affordability and simplicity by implementing ATmega microcontrollers, RTCs, LCDs, and buzzers for alerting users at pre-programmed times, proving useful for users unfamiliar with

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smartphones or internet-based systems. A more portable and robust solution was seen in [6], where a pill dispenser was designed for remote areas, avoiding internet dependency while still offering automatic alerts using an Arduino Nano and basic UI. To enhance real-time monitoring, [7] developed a system combining pill compartments with a GSM module and buzzer to notify users and caretakers about missed or upcoming doses. Further innovations in [8] and [9] explored the use of an Android application alongside Arduino and GSM modules, enabling alert messages to be sent automatically to both the patient and caregiver, making the solution user-friendly and responsive. In [10], a minimal yet efficient design was proposed using a GSM modem and real-time clock to alert patients of medication times and notify relatives in case of missed doses. Similarly, [11] focused on elderly-centric usability, combining IR sensors, microcontrollers, and SMS alerts to ensure dose accuracy and to track compliance. Offline solutions were also considered essential; [12] proposed a GSM-based medicine reminder system without IoT dependency, ensuring accessibility in regions with limited connectivity. In [13], researchers addressed the high cost and technical complexity of some systems by offering a simple microcontroller-based prototype that was both efficient and easy to manufacture. The concept of modular expansion was introduced in [14], allowing the user to increase or decrease the number of medicine compartments based on prescription needs. A broader scope was explored in [15] and [16], integrating smart pill boxes into the Internet of Medical Things (IoMT) ecosystem to collect, store, and share data with health professionals, although this required higher costs and infrastructure. Meanwhile, [17] provided a machine-learning-based model to detect patient compliance using historical medication patterns, providing predictive analysis to prevent missed dosages. On the other hand, [18] emphasized medication status monitoring with load cells, alarms, and fingerprint authentication, improving both safety and data logging. Several projects like [19] proposed voice-based reminders, integrating Arduino, MP3 modules, and touch sensors to help visually impaired users take medications properly. Another system in [20] integrated a touch-sensitive alarm mechanism and a camera module for real-time proof of medicine consumption, a feature useful for remote patient monitoring. In [21], a medicine dispenser incorporated fingerprint sensors and servo motors to allow only authenticated users to access their prescribed medication at the scheduled time, increasing safety in multi-patient environments. Expanding the personalization and connectivity scope, [22] proposed a smart dispenser system that stored health records on cloud platforms, enabling doctors to monitor adherence remotely. At the same time, [23] designed a reminder device combining Bluetooth modules and smartphone notifications, which was user-friendly and low-cost but required pairing with mobile devices. While most systems focused on physical reminders, [24] introduced emotional and behavioural cues using lighting patterns and voice modulation, aiming to positively influence medication-taking behaviour. In [25], the design moved toward complete automation using servo-controlled compartments and an app-based configuration system for reminders and user profiles. Studies like [26] emphasized secure access and minimal dependency by using fingerprint scanners, GSM modules, and RTCs, along with LEDs to show the medicine status. An emergency alert feature was explored in [27], which used an accelerometer to detect falls and trigger medicine dispensing and emergency contact messages. A smart service framework in [28] focused on the integration of IoT with healthcare services, suggesting software-defined, user-centric systems for elderly health support. In line with this, [29] designed a multi-functional health management system tailored for the elderly, with components like emergency help, telemedicine, health guidance, and personalized recommendations. These advancements reflect a growing recognition of the complex needs of elderly users. Additionally, the study in [30] provided a robust reminder system with airtight compartments, sound-based alerts, and pre-meal/post-meal instructions, ensuring medication safety and dosage accuracy. Synthesizing these works, the MediGuard 7X

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system was conceptualized to overcome key challenges observed in previous designs—such as high complexity, internet dependency, limited access security, and lack of effective user feedback. MediGuard 7X integrates multiple best practices from the reviewed literature, including scheduled dispensing via RTC (as seen in [1], [5], [10]), fingerprint-based authentication for secure access ([21], [26]), audio-visual reminders ([2], [6], [19]), and GSM communication for caregiver alerts ([7], [8], [10], [27]). Its standout feature is a locking mechanism using a solenoid lock, activated only during the medicine schedule via fingerprint scan, ensuring both safety and precision. Unlike systems requiring continuous internet access, MediGuard 7X works effectively offline using a GSM module, and unlike fully app-dependent models, it includes an LCD display for real-time feedback to the user. By unifying the ideas of modular design ([14]), emergency alerting ([27]), personalized interaction ([24], [29]), and simplicity ([3], [12]), MediGuard 7X represents an optimized balance between functionality, affordability, and elderly-cantered usability. It thereby offers a comprehensive, practical, and socially relevant solution for improving medication adherence among aging populations.

III. PROPOSED APPROACH

A. Problem statement

Medication non-adherence is a widespread and critical issue, particularly among elderly individuals and patients with special needs. These populations often face challenges such as memory decline, visual impairment, cognitive disorders, and lack of consistent caregiver support, making it difficult to follow complex medication regimens accurately. As a result, they are at a higher risk of missing doses, taking incorrect medications, or overdosing — all of which can lead to severe health complications, hospital readmissions, and increased mortality rates. The burden also extends to caregivers, who must constantly monitor patients and remind them to take their medications on time, leading to stress, burnout, and reduced quality of life. Traditional methods such as labelled pillboxes, handwritten schedules, or mobile reminders lack essential features like security, real-time validation, and foolproof confirmation that the correct medicine has been taken at the right time. Moreover, these manual systems are prone to human error and do not provide any deterrent against unauthorized access or medication misuse. The absence of biometric authentication and automation in current solutions compromises both the safety and independence of the user. To address these critical gaps, the **MediGuard 7X** project proposes a comprehensive smart medicine box that combines biometric (fingerprint) access, automatic servo-based locking mechanisms, RGB LED-guided visual alerts, real-time alarms using a buzzer and LCD, and time-based compartment activation. This system aims to provide a highly secure, accessible, and user-friendly interface that ensures timely medication intake, prevents errors, reduces caregiver workload, and ultimately promotes better health outcomes and patient autonomy.

B. Approach of Proposed System

1. Organized medication system: The box has seven compartments assigned to different times of the day, including options for before and after food. This setup ensures correct and timely medicine intake, reducing confusion and missed doses.

2. Time-based LED indicators: A green LED highlights the active compartment, while red LEDs indicate inactive ones. The DS3231 real-time clock maintains accurate timing for these indicators.

3. Fingerprint access control: Access is granted only to authorized users through a fingerprint sensor, preventing unauthorized handling of medicines and ensuring patient safety.

4. Buzzer alerts: A buzzer sounds at each scheduled time to remind the user to take medicine and continues until the fingerprint is authenticated.

5. Automatic lid closure: If the lid is left open, it automatically locks after 10 minutes to protect medicines from exposure, dust, or tampering.

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6. Caregiver refill mode: A caregiver can access the entire box for 30 minutes using their fingerprint to refill compartments, after which it auto-locks.

7. Security features: A solenoid lock, controlled by the Arduino Mega 2560, keeps the compartments secure and only unlocks after successful fingerprint verification.

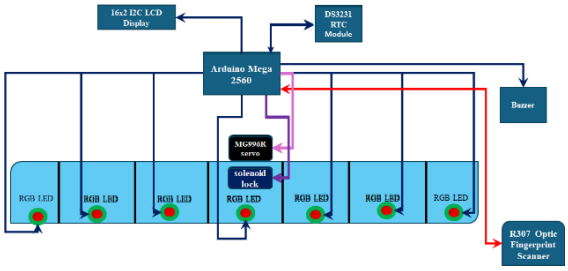

Figure 1: Block diagram of MediGuard 7X System

Figure 1 illustrates the **comprehensive block diagram of MediGuard 7X**, a smart, microcontroller-based medication dispensing system tailored for elderly and special-needs individuals. At the core of the design lies the **Arduino Mega 2560**, selected for its high I/O capacity and multiple serial communication ports, enabling seamless integration with all peripheral modules. The **R307 optical fingerprint sensor** acts as a biometric authentication layer, granting access only to registered users, thereby enhancing the system's security. Medication schedules are maintained with precision using the **DS3231 Real-Time Clock (RTC) module**, which triggers the system at predefined times.

Once activated, the system initiates both **visual and audible alerts** using RGB LEDs and a buzzer, respectively. The **RGB LED indicators** illuminate green to identify the correct medicine compartment and red for all others, ensuring the user selects the right dosage. Simultaneously, a **16x2 I2C LCD** provides clear, real-time guidance and reminders to the user. Upon successful fingerprint verification, the **MG996R high-torque servo motor** automatically lifts the lid, while the **solenoid lock** disengages to permit access only during the valid time window. After a specified interval, the lid closes, and the lock is re-engaged to prevent unauthorized access.

The entire system is powered by a **12V DC adapter**, and efficient voltage regulation is achieved using **LM2596S buck converters**, supplying stable power to all modules according to their requirements. By combining real-time automation, biometric security, and intuitive user alerts, **MediGuard 7X** offers a reliable and user-friendly solution for improving medication adherence and patient safety.

C. Hardware

1. Arduino Mega 2560: The Arduino Mega 2560 is a powerful microcontroller board based on the ATmega2560. It features 54 digital input/output pins, of which 15 can be used as PWM outputs, along with 16 analog inputs. Operating at a clock speed of 16 MHz, it offers 256 KB of flash memory for storing code and 8 KB of SRAM for dynamic data handling. This board is highly suitable for complex and advanced embedded applications requiring multiple sensors and actuators. Its numerous serial ports make it ideal for systems involving simultaneous communication with various modules, such as fingerprint sensors, real-time clocks, and displays.

2. Servo Motor (MG996R): The MG996R is a high-torque servo motor widely used in robotics and automation systems. It operates within a voltage range of 4.8V to 6.6V and can deliver torque up to 11 kg/cm. It offers a rotation speed of approximately 0.15 seconds per 60 degrees, allowing for precise control of angular motion. Its metal gear construction ensures durability and strength, making it suitable for high-load applications. In the context of MediGuard 7X, the servo motor is used to open and close the lid of the medicine box with precise control.

3. I2C LCD Display (1602): The 16 x 2 I2C LCD display is a 16-character by 2-line module equipped with an I2C interface, significantly reducing the number of microcontroller pins required for operation. Operating at 5V, it typically uses the I2C address 0x27. This display includes a blue

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backlight for better readability and is ideal for displaying real-time information, messages, and prompts to users. In the MediGuard 7X project, it is used to show medication reminders, system status updates, and personalized messages such as health tips or greetings.

4. Solenoid Lock (12V): A solenoid lock is an electromechanical device that controls access by moving a metal pin or latch in and out of a locking position. The 12V solenoid lock used in this system offers a holding force of approximately 0.25 kg and typically takes around one second to unlock when powered. It is compact, reliable, and energy-efficient, making it well-suited for secure access systems like lockers and medicine dispensers. In the MediGuard 7X, the solenoid lock ensures that the medication compartments remain securely locked until the correct time and authentication are provided.

5. Buck Converter (LM2596S): The LM2596S buck converter is a DC-to-DC step-down voltage regulator used to convert higher input voltages (such as 12V from an adapter) to a stable lower output voltage (such as 5V). This converter is highly efficient and provides adequate power to microcontrollers, sensors, and other 5V components. It prevents overvoltage damage and reduces power loss. In the MediGuard 7X system, this converter plays a crucial role in safely distributing power from the main supply to the various modules.

6. Optical Fingerprint Sensor (R307): The R307 fingerprint sensor is a biometric module that provides reliable fingerprint scanning and recognition. It operates within a voltage range of 4.2V to 6V and has a quick verification time of approximately 0.3 seconds. It can store up to 256 fingerprint templates, allowing multiple users to be authenticated. The sensor communicates with the microcontroller through a serial interface. In MediGuard 7X, it enhances security by ensuring that only authorized users can access the medicine box.

7. Relay Module (1-Channel 5V): A 5V single-channel relay module acts as an electrically operated switch that allows the microcontroller to control high-power devices, such as the solenoid lock or other external loads. This relay can handle currents up to 15A at 125V AC or 10A at 250V AC. It provides electrical isolation between the control circuit and the high-power circuit, enhancing safety. In the MediGuard 7X system, the relay is used to control the power flow to the solenoid lock.

8. RTC Module (DS3231): The DS3231 real-time clock module is a highly accurate timekeeping component with a built-in temperature-compensated crystal oscillator. It operates over an I2C interface and supports both 12-hour and 24-hour time formats. It retains accurate time even when the main power supply is turned off, thanks to its onboard battery backup. In the MediGuard 7X project, it is used to maintain precise timing for medication alerts and automated actions based on scheduled events.

9. Buzzer (5V): A 5V buzzer is a small electronic component used to produce sound alerts. It typically operates at a resonance frequency of around 2048 Hz. It is useful for generating beeps, alarms, or notification tones in electronic systems. In the MediGuard 7X device, the buzzer provides audio cues to remind users to take their medicine, enhancing accessibility for visually impaired or elderly individuals.

10. RGB LED: A RGB LED is a single LED package that combines red, green, and blue diodes. By adjusting the intensity of each diode, a wide range of colors can be produced. Each channel generally operates at a forward voltage of about 2.0V and a current of 20mA. In the MediGuard 7X system, RGB LEDs are used to indicate the active compartment (green for correct medicine, red for others), thereby providing intuitive and visual feedback to guide users during medicine retrieval.

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D. Circuit Diagram

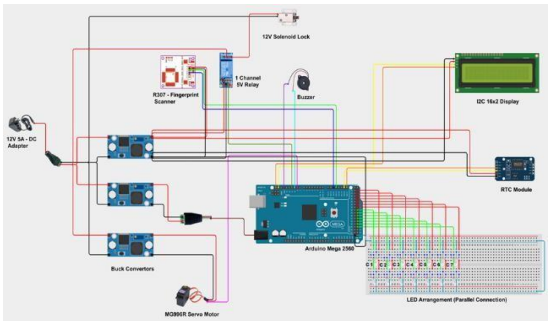

Figure 2: Circuit Diagram of MediGuard 7X

Figure 2 represents MediGuard 7X, a smart medication management system using the Arduino Mega 2560 as its central controller. The Arduino interfaces with an R307 fingerprint sensor via pins 16 (TX2) and 17 (RX2) for secure biometric authentication, ensuring only authorized users can access the medicine. A DS3231 real-time clock module connected through I2C (pins 20 and 21) manages precise scheduling of medicine times. At each scheduled time, a buzzer (pin 10) and green LED for the active compartment alert the user, while red LEDs indicate inactive compartments. The seven compartments have RGB LEDs connected across pins 23 to 49 for clear visual guidance. A high-torque MG996R servo motor on PWM pin 9 lifts the lid upon successful authentication. A solenoid lock controlled by a relay (pin 11) secures the box, unlocking only when both timing and fingerprint verification conditions are met. A 16x2 I2C LCD display shares the I2C bus (pins 20 and 21) to show real-time messages like greetings, date, time, and alerts. Power is supplied from a 12V 5A DC adapter stepped down by buck converters delivering 9V to the Arduino, 6.2V to the servo, and 5V to sensors and display modules. All components share a common ground for circuit stability. The system continuously monitors time, verifies user authentication, and grants access only during authorized intervals, preventing unauthorized use and ensuring medicines are taken correctly. MediGuard 7X offers a secure, automated, and user-friendly solution to improve medication adherence and safety for elderly and dependent individuals.

E. Flow Chart

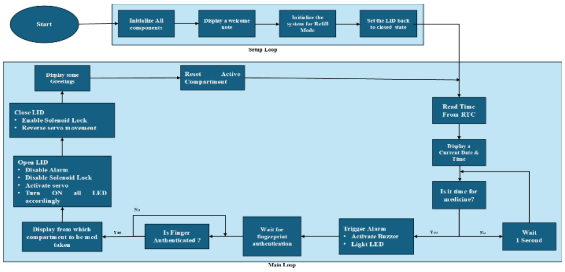

Figure 3: Flowchart of MediGuard 7X

Figure 3 illustrates the overall system flowchart of MediGuard 7X, capturing the intelligent decision-making and automation built into the device. This diagram traces the complete journey from powering up the system to the final steps of medication access and security monitoring. It begins with the initialization of the LCD screen, followed by the real-time display of current date and time. The system then continuously monitors for scheduled medicine times. Once a match is found, it activates the appropriate compartment by turning on a green LED while lighting red LEDs for all other sections, and triggers an alert via buzzer. Fingerprint authentication is then awaited to ensure that only the right person can access the medicine. If authenticated, the solenoid lock disengages, the lid opens to the optimal angle, and a visible countdown timer is displayed on the screen. In the absence of a valid fingerprint, the system escalates the alert with a continuous alarm. The detailed point-wise breakdown below explains each of these stages clearly, reflecting the sequence shown in *Figure 3*.

1. Initialize display:
   - Clear LCD screen
   - Set cursor to home position
   - Display default header
2. Update real-time clock display:
   - Fetch time from RTC module
   - Format as HH:MM:SS and display on LCD line 1
   - Fetch date as DD/MM/YYYY and display on LCD line 2

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3. Check medication schedule:
   - Compare current time with programmed schedule
   - If time matches any medication slot:
     i) Activate designated compartment:
        - Illuminate green LED for target compartment
        - Illuminate red LEDs for other compartments
        - Trigger the buzzer

     ii) Await fingerprint verification:
        - Correct fingerprint detected:
          - Deactivate buzzer
          - Unlock solenoid mechanism
          - Open lid to 110° position
          - Start 15-second countdown timer
          - Display remaining time on LCD
        - Incorrect/No fingerprint after 10 minutes:
          - Sound continuous alarm

F. Software Used

The Arduino IDE is open-source software used for writing, compiling, and uploading code to Arduino boards. It features a user-friendly interface suitable for beginners and experts. Key points include:

- Uses C programming language and supports many Arduino-compatible microcontrollers.
- Includes a built-in serial monitor for real-time debugging.
- Offers a wide range of libraries to simplify hardware integration.

  Important libraries used in this project:

  - Adafruit Fingerprint: Interfaces with the fingerprint sensor for biometric authentication.
  - Servo: Controls the servo motor for locking and unlocking mechanisms.
  - LiquidCrystal I2C: Manages the LCD display for clear user interaction.
  - DS3231: Supports the real-time clock module for accurate scheduling.

IV. EXPERIMENTAL RESULTS

Figure 4.1: Real-Time Clock Display during Idle Mode

Figure 4.2 Medicine Retrieval from Active Compartment

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Figure 4.3: LED-Based Guidance and Countdown Display

Figure 4.4: Greeting Message on LCD Display

The MediGuard 7X system proved to be a robust, dependable, and technically advanced innovation in the domain of smart healthcare devices, clearly demonstrating how the seamless integration of embedded electronics, real-time automation, and intelligent control mechanisms can offer a comprehensive solution to medication adherence challenges, particularly for elderly individuals and those with special needs. At the heart of this system, the Arduino Mega 2560 microcontroller effectively coordinated multiple hardware modules and executed synchronized tasks such as real-time clock polling, fingerprint authentication, motor actuation, solenoid locking, and LCD-based user feedback. Its selection was driven by the need for extended memory, multiple serial ports, and abundant I/O pins to accommodate components like the R307 fingerprint sensor, DS3231 RTC module, MG996R servo motor, a 5V relay module, and the 16x2 I2C LCD display. Each of these modules played a critical role in delivering reliable system functionality. The DS3231 module ensured highly accurate time tracking, essential for timely medication alerts, as seen during system idle mode in *Figure 4.1*, where the device displayed the current date and time on the LCD screen. The R307 fingerprint sensor added biometric security, enabling only authenticated users to access the medicine, while the MG996R servo motor, with its high torque and stability, allowed the lid to open and close smoothly at designated times. The RGB LED indicators visually guided the user by illuminating the correct medicine compartment in green while keeping other compartments lit in red to prevent confusion, a functionality clearly captured in *Figure 4.3*, which also displays the countdown timer indicating the time left before the lid closes automatically. The 16x2 LCD display proved highly effective in enhancing user interaction by delivering real-time feedback, prompts, countdowns, and encouraging messages such as “Your health is our priority,” as illustrated in *Figure 4.4*, reinforcing the system’s user-friendly nature and emotional engagement. During real-time simulations and testing, the system responded accurately to all seven medication time slots configured across the day: morning before and after food, noon before and after food, evening, and night before and after food. When the scheduled time arrived, the system triggered an auditory alert through the buzzer, simultaneously illuminated the designated compartment with green LEDs, and prompted the user via the LCD to authenticate using their fingerprint. Upon successful authentication, the solenoid lock disengaged, and the servo motor opened the lid to a fixed angle of 110 degrees, granting safe and unobstructed access to the medicine, as demonstrated in *Figure 4.2*. The compartment remained accessible for a countdown period of 15 seconds, which was clearly shown on the display for user awareness. If the fingerprint authentication was not performed, the buzzer would continue for two minutes, providing sufficient alert time without compromising security. Once the access window expired,

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the lid automatically closed and the solenoid re-engaged, restoring the compartment's secure state. Power management was another highlight of the system, ensuring uninterrupted functionality across all modules. A 12V 5A DC adapter powered the device, and the voltage was intelligently distributed using three LM2596S buck converters. These converters regulated output to 6.2V for the servo motor, 9V for the Arduino Mega 2560, and 5V for the fingerprint sensor, RTC module, relay, and LCD display. This power segmentation prevented voltage drop, electromagnetic interference, and overheating, improving system longevity and performance even under continuous operation. Throughout user testing, each module performed consistently and reliably, even when multiple components operated simultaneously. Furthermore, the user interface design was tailored specifically for ease of use by elderly individuals. Upon startup, the device displayed a warm welcome and live date and time, transitioning into a refill prompt when necessary. During refill mode, the lid remained open for two minutes, allowing easy loading of tablets into each labelled compartment. Between doses, the LCD served as a continuous time display and readiness indicator. During active alert mode, the combination of sound, light, and text provided a multisensory experience that guided the user intuitively. The inclusion of motivational messages like those shown in *Figure 4.4* enhanced user comfort and fostered a sense of companionship, which is crucial in healthcare environments. This thoughtful blend of technology and empathy positioned MediGuard 7X not just as an automated pillbox, but as a proactive health assistant. Through consistent performance, precision in timing, effective security protocols, and intuitive user interaction, the system proved to be a dependable, scalable, and socially impactful solution for medication management in both domestic and institutional settings.

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Event Management System

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Abstract—The Event Management System is a dynamic and innovative platform designed to revolutionize the way events are planned, managed, and executed. The concept of event coordination has evolved over time, transitioning from traditional manual processes to sophisticated digital solutions. This system aims to streamline the event lifecycle, offering seamless registration, automated scheduling, real-time notifications, and intuitive attendee management. With its structured architecture and scalable framework, it ensures a hassle-free experience for both organizers and participants.Developed using modern web technologies, the system leverages React.js for the frontend and Spring Boot for the backend, creating a responsive and interactive user interface while ensuring robust backend processing. The integration of relational databases (MySQL/PostgreSQL) facilitates structured data management, while role-based access control (RBAC) ensures secure and efficient user interactions. Enhancing engagement, the system incorporates automated email/SMS alerts, AI-driven recommendations, and cloud-based data accessibility, allowing for smooth event execution.Security and reliability are at the core of this system, with JWT-based authentication, encrypted transactions, and payment gateway integration enabling secure ticketing and data protection. Designed to minimize manual workload, reduce errors, and enhance collaboration, this Event Management System transforms conventional event planning into a digitally-driven, highly efficient, and user-friendly process. The combination of cutting-edge technology and intelligent automation ensures that events are managed with precision, efficiency, and ease, making it an indispensable tool for modern event coordination

I. Introduction

Event management is a crucial aspect of organizing and executing various types of events, such as conferences, corporate meetings, weddings, and social gatherings. Traditional event planning methods often involve manual coordination, leading to inefficiencies, miscommunication, and time-consuming processes. With the advancement of technology, digital solutions have emerged to streamline event management, improving efficiency and user experience. The Event Management System is a web-based application designed to simplify the process of event planning, organization, and execution. This system enables event organizers to create, manage, and monitor events seamlessly while allowing attendees to register and receive event-related updates. The project is developed using React.js for the frontend, ensuring a dynamic and interactive user interface, and Spring Boot for the backend, which handles business logic, authentication, and data storage. By leveraging a client/server architecture, the system ensures smooth communication between the frontend and backend through RESTful APIs. It also incorporates a relational database like MySQL or PostgreSQL to manage event-related data efficiently. The system provides essential features such as event creation, attendee registration, notifications, and role-based access control, making event management more convenient and automated. This project aims to enhance event organization by reducing manual efforts, minimizing errors, and improving communication between stakeholders. With potential future enhancements such as AI-driven event recommendations, payment gateway integration, and real-time communication features, the system can further improve the overall event management experience.

II. MOTIVATION AND OBJECTIVES

Event management has always been a challenging task, requiring meticulous planning, coordination, and execution to ensure a seamless experience for attendees. Traditional event planning methods, which involve manual registrations, phone calls, emails, and paperwork, often lead to inefficiencies, miscommunication, and scheduling conflicts. With the rapid advancement of technology and digital transformation,there is a growing need for an automated, intelligent, and user-friendly event management system that simplifies the process while enhancing efficiency. The motivation behind developing this Event Management System (EMS) is to provide a centralized, scalable, and efficient platform that automates event planning, improves coordination, and enhances user engagement. By leveraging modern web technologies such as React.js for the frontend and Spring Boot for the backend, the system aims to streamline the workflow, reduce human effort, and minimize errors. The integration of cloud-based services, automated notifications, and secure payment gateways ensures that event organizers and attendees have a hassle-free experience. Moreover, in the post-pandemic era, virtual and hybrid events have gained significant traction, necessitating a robust digital solution that can handle online registrations, real-time updates, and interactive participation. This project is driven by the need to bridge the gap between

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traditional event management and modern technological advancements, making event planning more efficient, secure, and accessible to a wider audience. The Event Management System is designed to streamline the process of event planning and execution by providing an automated, user-friendly, and efficient platform. Traditional event management often involves manual coordination, leading to inefficiencies, scheduling conflicts, and communication gaps. This system aims to address these challenges by offering a centralized digital solution that enables organizers to create, manage, and track events while allowing attendees to register and receive updates seamlessly. By leveraging React.js for the frontend and Spring Boot for the backend, the system ensures a scalable, secure, and responsive experience. The platform integrates key functionalities such as automated notifications, real-time updates, role-based access control, and data management to improve efficiency and minimize human errors. Additionally, it lays the foundation for future enhancements like AIdriven event recommendations, payment gateway integration, and real-time communication features to further enhance user engagement and event success. Key Objectives:

- Automate Event Planning – Reduce manual effort through an interactive platform for event creation and management.
- Enhance Communication – Provide automated email/SMS notifications and real-time updates for organizers and attendees.
- Ensure Scalability and Accessibility – Develop a webbased system accessible from any device with an internet connection.
- . Implement Secure Authentication – Use role-based access control (RBAC) to restrict access based on user roles.
- Optimize Data Management – Store and retrieve eventrelated data efficiently using a relational database.
- Improve User Experience – Offer an intuitive UI with features like search filters, calendar views, and event categorization.
- Minimize Errors and Manual Work – Automate registration, attendance tracking, and scheduling to prevent mistakes.
- Enable Future Expansion – Support AI-based recommendations, payment gateways, and live chat features for better functionality

The Event Management System is designed to be an efficient, scalable, and secure solution that simplifies the event planning process while enhancing user engagement. By integrating modern web technologies and automation, the system reduces manual efforts, improves event coordination, and ensures a seamless experience for both organizers and attendees. The project also lays the foundation for future improvements, making it a robust and future-ready solution for event management

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III. RELATED WORKS

Event Management Systems (EMS) have become essential for efficiently organizing, managing, and analyzing events. In their study, D. A. Shah, H. Vasudavan, and N. F. Razali discuss EMS as digital platforms that streamline event planning, ticketing, attendee management, and feedback collection [1]. These systems integrate features such as automated ticket booking, real-time attendee tracking, digital payment processing, and data-driven feedback collection. The paper highlights that EMS has transformed the event industry by reducing manual efforts, improving efficiency, and enhancing user experiences. Key features of EMS include online registration and ticketing, secure payment processing, attendee engagement tools, and data analytics for event performance tracking. Despite its advantages, EMS adoption faces challenges such as data security risks, technical barriers, and usability concerns. The study also explores advancements like AI-powered automation, blockchain-based ticketing, and augmented reality (AR) for immersive event experiences.The authors conclude that EMS has revolutionized event management by making it more structured and user-friendly. Future developments, including AIdriven automation and enhanced cybersecurity, are expected to further enhance EMS capabilities. This literature review provides valuable insights into how digital tools contribute to a comprehensive EMS, improving event planning, execution, and post-event evaluation. In their review paper, A. Saleem, D. A. Bhat, and O. F. Khan explore the significance of Event Management Systems (EMS) in modern event planning and execution. The study, published in the International Journal of Computer Science and Mobile Computing, highlights how EMS streamlines event organization by integrating various functions such as event scheduling, ticketing, resource allocation, and real-time monitoring [2]. The authors emphasize that the adoption of EMS reduces human errors, enhances coordination among stakeholders, and improves the overall efficiency of event planning. The paper categorizes EMS into different types, including web-based and mobile-based platforms, each offering distinct advantages in terms of accessibility and user engagement. Additionally, it discusses the role of cloud computing in EMS, enabling remote access to event data and facilitating collaboration between organizers and participants. The study also identifies key challenges in EMS implementation, such as security concerns, system scalability, and the need for user-friendly interfaces.

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Furthermore, the authors analyze emerging trends in EMS, such as artificial intelligence (AI)-driven automation, big data analytics for event insights, and IoT-enabled smart event solutions. They conclude that while EMS has transformed event management, continuous technological advancements and improved cybersecurity measures are necessary for its future growth. This review provides valuable insights into the evolution of EMS and its impact on the efficiency and effectiveness of event organization. In the study ”Artificial Intelligence Applications for Event Management and Marketing,”F. Do˘ganay Ergen explores the transformative role of Artificial Intelligence (AI) in modern event planning, execution, and promotion [3]. Published as a chapter in Impact of ICTs on Event Management and Marketing (IGI Global, 2021), the study highlights how AI-powered solutions enhance event efficiency, audience engagement, and data-driven decisionmaking. The author discusses several AI applications in event management, including chatbots for customer service, automated scheduling systems, personalized marketing campaigns, and **predictive analytics for attendee behavior. AI-driven automation minimizes human intervention in repetitive tasks, such as ticketing and registration, allowing event organizers to focus on strategic decision-making. The study also highlights the role of AI in marketing, where machine learning algorithms analyze user preferences to deliver targeted advertisements and optimize event outreach.Furthermore, the paper examines AIpowered analytics tools that process large datasets to provide insights into attendee engagement, sentiment analysis, and event success metrics. AI-driven recommendation engines also personalize event experiences by suggesting relevant sessions, networking opportunities, and content based on user interests. The study acknowledges the challenges of AI adoption, such as ethical concerns, data privacy issues, and the need for skilled professionals to manage AI-driven systems.In conclusion, Ergen emphasizes that AI is revolutionizing event management by making processes more efficient, improving audience interaction, and providing valuable insights through data analytics. The research underscores the growing reliance on AI in the industry and predicts further advancements in AIdriven automation, virtual event experiences, and intelligent decision-making systems for event planning and marketing. P. Arora, M. Gaur, H. Jaisingh, R. Pandey, and T. Rustagi (2023), in their study ”Developing Event Management Web Application”, discuss the development of a web-based EMS designed to automate event planning and attendee management [4]. Their research highlights key functionalities such as online event registration, automated scheduling, ticket generation, and real-time notifications. The study emphasizes that web applications improve event efficiency by providing a centralized platform where organizers can manage multiple event-related tasks seamlessly. The research also explores the use of interactive dashboards and data visualization tools to enhance user experience. R. Kumar, A. Prakash, and M. Bansal (2020) explore the use of blockchain technology for secure and transparent event ticketing [5]. In their paper ”BlockchainBased Event Ticketing System for Secure and Transparent Transactions”, the authors propose a decentralized system that eliminates fraudulent ticketing, unauthorized resales, and data tampering. Blockchain technology ensures that ticket transactions are immutable, verifiable, and tamper-proof, reducing issues such as fake tickets and overbooking. The study demonstrates how smart contracts can automate refund policies and secure ticket transfers while maintaining data privacy for attendees. A. Kumar, S. Gupta, and M. Sharma (2018) focus on cloud computing as a solution for large-scale event management/ [6]. Their paper ”A Cloud-Based Event Management System for Large-Scale Conferences” presents an architecture where cloud platforms provide scalability, flexibility, and real-time accessibility for event organizers. The research highlights that cloud-based EMS reduces infrastructure costs, ensures remote access to event data, and allows for dynamic resource allocation based on demand. The paper also explores real-time data synchronization, which improves attendee engagement and speaker coordination. Similarly, S. Sharma, A. Yadav, and R. Gupta (2020) extend the discussion on cloud-based EMS by incorporating data analytics for improved decisionmaking [7]. Their study, ”Event Management System with Cloud Integration and Data Analytics”, highlights how big data techniques can be used to analyze attendee behavior, optimize event scheduling, and enhance audience engagement. The research demonstrates how predictive analytics can be used to forecast event attendance, suggest personalized event recommendations, and improve marketing strategies.

IV. System Design and Architecture

A. Architecture Overview

The Event Management System (EMS) adopts a microservices-based architecture to ensure scalability, maintainability, and modularity. The architecture consists of the following primary components:

1) Frontend: The user interface is developed using React.js, a modern JavaScript library that facilitates the creation of dynamic and responsive web applications. React.js supports dynamic routing through React Router, enabling seamless navigation between views without full page reloads. The UI is constructed with modular,

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reusable components to enhance code maintainability and ease of updates.

2) Backend: The backend services are implemented using the Spring Boot framework, which provides a robust environment for building RESTful APIs. These APIs encapsulate the core business logic, including event registration processing, user management, and scheduling functionalities. Additionally, the backend manages authentication and authorization mechanisms to secure access to protected resources.
3) Database: Data persistence is handled by a MySQL relational database. MySQL is utilized for storing structured data such as user profiles, event details, registration records, and transaction logs. The relational model supports data integrity and complex querying requirements, while transaction logging ensures accountability and facilitates rollback operations if needed.
4) Security: The system employs JSON Web Tokens (JWT) in conjunction with Spring Security to provide stateless authentication and authorization. Upon successful user login, a JWT is issued and used to authenticate subsequent API requests. This approach enhances security by minimizing server-side session storage and supports scalable deployment.

The modular design of the EMS allows individual components to be developed, deployed, and scaled independently, providing flexibility to handle varying workloads effectively. Furthermore, the architecture supports integration with third-party APIs, including payment gateways, messaging services, and analytics platforms, thereby extending the system's capabilities and enabling future enhancements with minimal disruption.

B. Major Modules

The EMS system is composed of several core modules, each responsible for distinct functionalities and communicating through well-defined APIs to ensure modularity and maintainability:

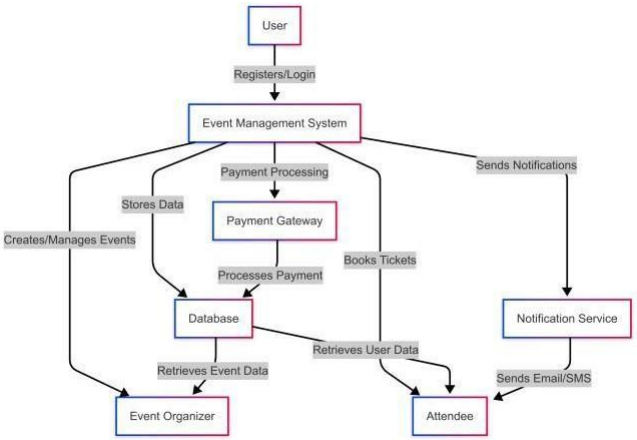

Fig. 1. System Architecture

1) Authentication: This module implements secure user authentication using JSON Web Tokens (JWT). It manages login sessions, token issuance, and validation to protect system resources from unauthorized access.
2) Event Management: Administrators utilize this module to create, update, and delete event information. It maintains event schedules, descriptions, and capacity details, ensuring accurate event lifecycle management.
3) Registration: This module allows users to browse available events and register accordingly. It handles user inputs, registration validation, and stores participant data.
4) Ticketing: Upon successful payment, this module generates tickets for users. It integrates with payment gateways and issues digital tickets that can be verified at event entry points.
5) Notification: Automated notifications are sent via email and SMS to keep users informed about event updates, registration confirmations, and reminders. This module supports communication workflows and ensures timely delivery of alerts.
6) Feedback: After events conclude, this module collects user feedback through surveys. The data is analyzed to assess event success and inform future improvements.

Each module operates independently and interacts with others through RESTful APIs, promoting loose coupling, facilitating debugging, and enabling individual module scalability.

V. Datasets and Workflow

The dataset for an Event Management System includes structured data representing users, events, tickets, payments,

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and other related information. This dataset is crucial for managing event registrations, ticket bookings, payments, and user interactions. Below are the key datasets used in an event management project: The User dataset maintains details of all registered users, including attendees and event organizers, with unique IDs, contact details, and roles. This data is crucial for authentication, role-based access, and personalization. The

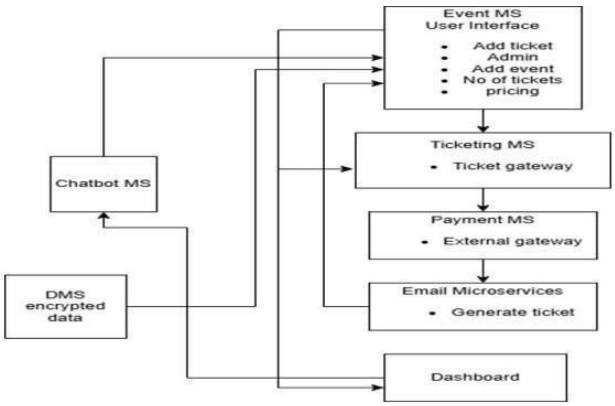

Fig. 2. DataFlow Diagram

Event dataset records all events created on the platform, capturing details like event name, category, location, date, ticket pricing, and availability. This data set helps in managing event listings and tracking upcoming events. The Ticket dataset keeps a record of ticket bookings, linking users to their purchased tickets and tracking ticket statuses, such as confirmed or pending. The Payment dataset manages financial transactions, storing information about payment amounts, methods (such as credit cards or PayPal), and transaction statuses to ensure smooth and secure ticket purchases. The Feedback and Reviews dataset collects user ratings and comments, allowing event organizers to assess attendee satisfaction and improve future events. The Admin System Logs dataset records all system activities, tracking actions like event creation, ticket updates, and payments for auditing and security purposes. Together, these datasets create a structured and efficient system for event management, ensuring seamless user experiences and reliable transaction processing

VI. Implementation Details

The development of the Event Management System begins with the Planning and System Design phase. This stage involves gathering requirements, defining system functionalities, and selecting the appropriate technology stack. Key features such as event creation, ticket booking, payment integration, and user authentication are identified. The system architecture is designed using React.js for the frontend, Spring Boot for the backend, and MySQL/PostgreSQL for database management, ensuring a scalable and efficient structure. During the Development and Implementation phase, the frontend is developed using React.js, incorporating Material UI or Tailwind CSS for a responsive user interface and Redux Toolkit for state management. The backend, built with Spring Boot, consists of RESTful APIs, Spring Security for authentication, and Spring Data JPA for database operations. Payment gateways such as Stripe or PayPal are integrated for secure transactions. This phase follows an iterative approach, ensuring continuous improvements and feature enhancement . The Testing and Security Assurance phase ensures that the system is robust and secure. Unit testing is conducted using JUnit and Mockito, while integration testing is performed using Postman and REST Assured to validate API functionality. The frontend undergoes Jest and React Testing Library tests to ensure a smooth user experience. Additionally, security testing is performed to prevent vulnerabilities such as SQL injection, CORS misconfigurations, and XSS attacks, ensuring data integrity and system security. In the Deployment and Maintenance phase, the frontend is hosted on Vercel, Netlify, or AWS S3, while the backend is deployed on AWS EC2, Heroku, or Docker Containers. The database is managed on AWS RDS or Firebase, ensuring efficient data handling. CI/CD pipelines, implemented using GitHub Actions, Jenkins, or GitLab CI/CD, enable automated deployment and updates. Regular monitoring and maintenance ensure that the system remains functional, scalable, and secure for users.

VII. Results and Evaluation

The EMS was evaluated across multiple critical functionalities to assess performance, security, and user satisfaction:

- Login Functionality: The authentication mechanism demonstrated secure and responsive user logins, effectively safeguarding access through JWT-based token validation.
- Event Scheduling: Administrators were able to create and update events in real-time without noticeable delays, confirming the backend's capability to handle dynamic event management.
- Payment and Ticketing: Payment processing and ticket generation were successfully verified using sandbox environments, ensuring the correctness of transaction workflows and ticket issuance.

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User acceptance testing revealed high satisfaction scores, particularly regarding the system's ease of use and the responsiveness of the user interface design.

VIII. Conclusion and Future Work

In conclusion, the Event Management System built using Java Spring Boot as the backend and React as the frontend successfully achieves the intended objectives of providing a robust, scalable, and user-friendly platform for managing events. By leveraging Spring Boot's powerful REST APIs and React's dynamic, component based architecture, the application ensures seamless communication between the client and server, resulting in a responsive and efficient user experience.The backend, powered by Spring Boot, ensures secure data handling, smooth authentication, and streamlined operations for event creation, modification, and deletion. Meanwhile, the React-based frontend delivers a clean, interactive interface that enhances user engagement and accessibility. The application's modular design also allows for future enhancements, such as integrating real-time features, expanding functionalities, and improving user personalization. Overall, this project demonstrates the effectiveness of combining modern technologies like Java Spring Boot and React to create a full-stack application that meets contemporary standards in web development. Future improvements could include the addition of advanced analytics, improved security measures, and better scalability options to cater to a broader audience.

Acknowledgment

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ARDUINO NANO BASED LANDSLIDE DETECTION SYSTEM WITH GSM ALERT

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***Abstract*-Landslides are one of the most devastating natural disasters, often triggered by heavy rainfall, soil saturation, and seismic activity. They pose a serious threat to life, infrastructure, and the environment, particularly in hilly and mountainous regions. Early detection and timely warnings are essential for reducing the impact of such disasters. This project aims to develop a low-cost, efficient, and real-time landslide detection system using embedded technology to provide early alerts and improve disaster preparedness.The primary objective of the project is to monitor key environmental parameters that indicate ground instability and issue alerts before a landslide occurs. The system continuously observes changes in soil moisture, ground vibration, and slope tilt, which are known precursors to landslides. When abnormal conditions are detected, it activates local alerts and sends warning messages to users via GSM communication.The methodology involves integrating sensor data into an Arduino Nano microcontroller, which processes the information and compares it with predefined safety thresholds. If a risk is identified, the system triggers an audible and visual alert, along with a remote notification via SMS.**

KEYWORDS: Arduino nano,Sw-420 vibration Sensor, Soil moisture sensor,Adxl345 accelerometer ,SIM GSM module

I. INTRODUCTION

The Landslide Detection System project aims to address the critical issue of landslides,which can lead to devastating consequences for communities in vulnerable regions.By integrating advanced sensor technology, including a soil moisture sensor, a vibration sensor, and an accelerometer, this system continuously monitors environmental conditions that may indicate an impending landslide. The Arduino Nano microcontroller serves as the central processing unit, analyzing data from these sensors to determine whether the measured parameters exceed predefined safety thresholds. In the event of a potential landslide, the system activates visual alerts through LEDs and a buzzer, while also utilizing a GSM module to send immediate SMS notifications to designated recipients. This project not only showcases the practical application of embedded systems in environmental monitoring but also emphasizes the importance of timely alerts in enhancing public safety and disaster preparedness. Ultimately, the Landslide Detection System represents a proactive approach to mitigating risks associated with landslides, potentially saving lives and protecting property in at-risk areas.

II. PREVIOUS WORKS

It utilizes sensor-based monitoring, incorporating soil moisture sensors, vibration sensors, and accelerometers to detect early signs of landslides. An Arduino-based microcontroller processes sensor data, aligning with the embedded system approach discussed in the literature. Additionally, threshold-based decision making is implemented, where sensor readings are analyzed to assess potential risks. The system features alert mechanisms such as LED indicators, buzzers, and GSM-based SMS notifications, ensuring timely warnings for at-risk communities. By adopting these concepts, the system provides a cost-effective and practical solution for early detection and disaster preparedness, minimizing the risks associated with landslides.[1]

The project adopts the sensor-based monitoring approach discussed in both studies, integrating soil moisture sensors, vibration sensors, and accelerometers to detect early signs of landslides. Additionally, the use of an Arduino-based microcontroller aligns with embedded system applications highlighted in the literature. The alert mechanisms, including LED indicators, buzzers, and GSM-based SMS notifications, reflect the importance of early warning systems emphasized in previous research While the literature explores advanced multi-parameter monitoring, machine learning models, and IoT-based communication, the project simplifies these concepts into a cost- effective, threshold-based landslide detection system, making it practical for realworld implementation.[2]

The project adopts the concept of using soil moisture sensors to track changes in saturation levels, which is crucial for detecting landslide risks. The literature emphasizes high-resolution saturation prediction models, which could enhance the system's accuracy by refining threshold-based decision-making. While the project relies on fixed safety thresholds, the study suggests optimizing these values using realtime soil moisture data analysis. Integrating dynamic saturation models could improve the system's ability to predict landslides more precisely, reducing false alarms and enhancing overall reliability.[3]

The study highlights the importance of calibrating soil moisture sensors based on local soil conditions, which could enhance the accuracy of threshold values in the project. Additionally, the laboratory-based approach in the literature suggests optimizing sensor placement and data interpretation to improve reliability. Applying these insights could refine the threshold-based decision-making process, reducing false alerts and ensuring more precise landslide detection.[4]

The study emphasizes tracking soil moisture saturation levels to predict landslides, which aligns with the project's use of soil moisture sensors for real-time monitoring. While the project relies on fixed threshold values to assess landslide risk, the literature suggests dynamic prediction models that adjust thresholds based on real-time saturation trends. Implementing this approach could improve the system's accuracy by reducing false alarms and enhancing early warnings. Additionally, insights from the literature on long-term soil moisture trends could help refine the detection system for better performance in varying environmental conditions[5]

The study demonstrates how the ADXL345 accelerometer can effectively measure earth's free-fall acceleration, which aligns with the project's use of an accelerometer sensor to detect ground movements that may indicate a potential landslide. The literature highlights calibration techniques and data processing methods for improving measurement accuracy, which could enhance the system's ability to detect subtle vibrations or shifts in terrain. Implementing these insights could lead to more precise motion detection, improving the reliability of the landslide warning system[6]

The study explores vibration characteristics and data interpretation, which aligns with the project's implementation of an accelerometer sensor to detect ground movements related to landslides. The literature highlights signal processing techniques and noise reduction methods, which could enhance the accuracy of vibration detection in the system. Applying these insights could improve the reliability of accelerometer readings, ensuring better identification of abnormal ground movements and reducing false alarms in the landslide warning system. [7]

The study demonstrates how an Arduino-based system can effectively send realtime SMS alerts and activate alarms when detecting ground movement, which aligns with the project's implementation of a GSM module for SMS notifications and buzzer alerts. The literature highlights message optimization techniques to ensure timely and efficient alerts, which could improve the notification system's reliability in emergency situations. Applying these insights could enhance the alert mechanism, ensuring that warnings are promptly and accurately delivered to at-risk communities.[8]

The study shows that soil moisture levels do not stay the same and change with weather conditions, which helps in better landslide prediction. The project already uses soil moisture sensors, but applying this idea could make the system more accurate by analyzing moisture patterns instead of just using fixed limits. This can help in better early warnings and fewer false alarms.[9]

The study highlights how solar panels can provide a sustainable power source, making the system more reliable, especially in remote or disaster-prone areas where electricity access may be limited. While the project already integrates a GSM module for sending SMS notifications, incorporating solar power could enhance energy efficiency, system longevity, and uninterrupted monitoring. This approach would ensure that the detection system remains functional even during power outages, improving its reliability in real-world applications.[10]

The literature emphasizes the importance of considering variations in environmental conditions, which could enhance the project by refining threshold adjustments based on real-time data trends. While the project focuses on predefined sensor limits,incorporating a more adaptive threshold system could help reduce false alarms and improve early warning reliability.[11]

The literature emphasizes the importance of continuous monitoring and datadriven decision-making, which aligns with the project's use of sensors to detect early warning signs. While the project focuses on alert mechanisms like buzzer and SMS notifications, the study highlights the need for a structured response system to manage risks effectively. Implementing data logging and trend analysis could improve longterm monitoring, allowing for better assessment of landslide-prone areas and more informed decision-making in disaster management.[12]

III. BLOCK DIAGRAM

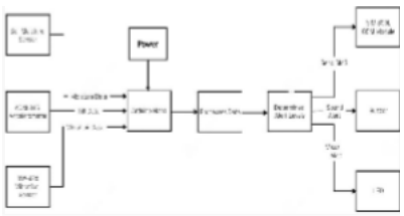

Figure 1: Block diagram

This block diagram illustrates a Landslide Detection and Early Warning System designed to monitor environmental conditions in real time and provide timely alerts when potential landslide threats are identified. At the core of the system is the Arduino Nano, a compact, low-power microcontroller that manages data from various sensors and controls the output alert devices. The system is designed to be deployed in landslide-prone areas, particularly in hilly and mountainous regions, where early detection is critical for minimizing damage and saving lives.The system integrates three key sensors: a soil moisture sensor, an ADXL345 accelerometer, and an SW-420 vibration sensor. These sensors work together to provide comprehensive environmental monitoring. The soil moisture sensor is responsible for detecting the amount of water present in the soil. When moisture levels rise significantly—such as during heavy rainfall or rapid snowmelt—the soil can become saturated and lose its structural integrity, increasing the likelihood of a landslide. For example, if the soil moisture exceeds a threshold like 80.

The ADXL345 accelerometer is a 3-axis sensor that detects changes in orientation,tilt, and acceleration. These vibrations could result from seismic activity, ground cracking, or initial soil movement and often serve as a warning sign of an impending landslide.All sensor data is continuously transmitted to the

Arduino Nano, which processes the readings based on predefined thresholds. The microcontroller uses conditional logic to analyze data patterns and determine whether the detected values indicate a potential landslide. If the conditions meet or exceed danger levels—for example, high moisture combined with noticeable ground tilt or vibrations—the system concludes that a landslide risk is present.In response, the Arduino Nano activates multiple alert mechanisms to ensure that nearby individuals and remote authorities are warned in time. A buzzer is triggered to produce a loud, immediate sound alert to anyone within audible range.

IV. CIRCUIT DIAGRAM

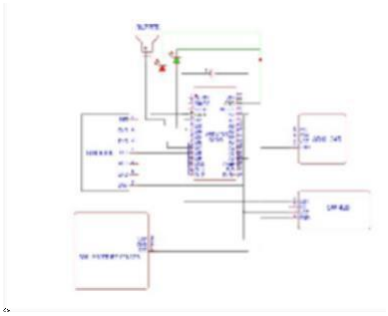

Figure 2: Circuit Diagram

This circuit diagram represents a landslide detection and early warning system using an Arduino Nano, which acts as the central processing unit that collects data from multiple sensors, processes it, and activates alerts when necessary. The soil moisture sensor measures soil water content and sends the data to the Arduino through an analog input pin, helping to assess the risk of soil saturation, while the ADXL345 accelerometer detects changes in ground tilt and movement via the I2C interface (SCL and SDA pins), and the SW-420 vibration sensor monitors ground vibrations and provides a digital output that indicates sudden ground movements. The system operates by continuously analyzing the data collected from these sensors and determining whether the detected values exceed predefined safety limits, which could indicate a potential landslide. When the system detects a high-risk condition, it triggers an alert mechanism that includes a buzzer, which produces a loud warning sound, and LED indicators, which provide a visual alert. Additionally, the SIM800L GSM module. is used to send SMS notifications via TX and RX communication when a landslide risk is detected, allowing remote alerts to be sent to authorities or individuals for timely action. The power supply for the system is managed through the 5V and GND pins of the Arduino Nano, ensuring proper functionality, while an external 5V power supply stabilizes the GSM module's operation. The connections between components are carefully structured, with the buzzer connected to D3, LEDs to D4 and D5, the SIM800L GSM module interfacing via D9 and D10, the ADXL345 accelerometer through A4 and A5 (SDA/SCL), the SW-420 vibration sensor to D2, and the soil moisture sensor to A0, ensuring an efficient layout for data collection, processing, and alert activation. This system provides real-time monitoring of environmental conditions, early detection of landslide risks, and immediate alerts through sound, light, and SMS notifications, making it a valuable tool for disaster prevention and response.

V. COMPONENTS USED

A) ARDUINO NANO

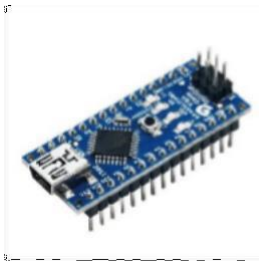

Figure 3: Arduino Nano

In a Landslide Detection System, the Arduino Nano acts as the core controller, efficiently managing sensor data, executing logic, and controlling output components.Powered by the ATmega328P microcontroller, the Arduino Nano provides a compact yet powerful platform that supports both simple and complex operations. Its small size allows for seamless integration into space-constrained environments, such as remote monitoring stations in hilly or mountainous regions. The board is equipped with 14. digital I/O pins and 8 analog input pins, allowing it to interface with a wide range of sensors including soil moisture sensors, vibration sensors, and tilt sensors.

B) SW-420 VIBRATION SENSOR

Figure 4: Sw-420 Vibration Sensor

The SW-420 Vibration Sensor is a compact and effective sensor designed to detect vibrations and movements, making it suitable for various applications, including security systems and environmental monitoring. It operates on a simple principle:when vibrations occur, the sensor's internal switch closes, sending a digital signal to the connected microcontroller. This sensor is particularly useful in detecting ground movements that may indicate potential landslide conditions, as it can sense even minor vibrations. The SW-420 is easy to integrate into projects, requiring only a power supply and a connection to a digital input pin on a microcontroller, such as the Arduino Nano. It typically operates at a voltage of 3.3V to 5V, making it compatible with most microcontroller platforms. The sensor's sensitivity can be adjusted using a potentiometer, allowing users to fine-tune its response to different vibration levels. With its straightforward design and reliable performance, the SW-420 Vibration Sensor plays a crucial role in the Landslide Detection System by providing real-time data on ground vibrations, enabling timely alerts and enhancing safety

measures in vulnerable areas.

C) SOIL MOISTURE SENSOR

Figure 5 : Soil Moisture Sensor

The Soil Moisture Sensor is an essential device used to measure the volumetric water content in soil, providing critical data for agricultural and environmental applications. It typically consists of two probes that are inserted into the soil,where they measure the electrical resistance or capacitance, which varies with the moisture level present. When the soil is wet, the resistance decreases, allowing for a higher current to flow, while dry soil exhibits higher resistance, resulting in lower current flow. This sensor usually outputs an analog voltage signal that corresponds to the moisture level, which can be easily read by a microcontroller, such as the Arduino Nano.Operating at a voltage range of 3.3V to 5V, the Soil Moisture Sensor is compatible with most microcontroller platforms, making it straightforward to integrate into various projects. Its simple design and low cost make it an attractive option for monitoring soil conditions in real- time. In the context of the Landslide Detection System, the Soil Moisture Sensor plays a vital role by continuously monitoring soil moisture levels, which can indicate saturation and potential landslide risk.

D) ADXL345 ACCELEROMETER

Figure 6: Adxl345 Accelerometer

The ADXL345 is a highly versatile, low-power, three-axis accelerometer that is widely used in various applications, including motion sensing, tilt detection, and vibration monitoring. It features a digital output interface, allowing for easy integration with microcontrollers such as the Arduino Nano via I2C or SPI communication protocols.The ADXL345 can measure acceleration in three dimensions (X, Y, and Z axes) with a selectable range of Å}2g, Å}4g, Å}8g, or Å}16g, making it suitable for a wide range of applications, from wearable devices to industrial equipment.One of the key advantages of the ADXL345 is its low power consumption, which enables battery operated devices to operate for extended periods without frequent recharging.

E) SIM 800L GSM MODULE

Figure 7: Sim 800l Gsm Module

The SIM800L is a compact GSM module that enables devices to communicate over mobile networks, allowing for SMS messaging, voice calls, and internet connectivity.Operating on a voltage range of 3.4V to 4.4V, it is designed for low power consumption, making it ideal for battery-powered applications. The module supports AT commands for easy integration with microcontrollers like the Arduino Nano and can connect to various frequency bands (GSM 850/900/1800/1900 MHz) for global use. In the Landslide Detection System, the SIM800L is crucial for sending SMS alerts to users when potential landslide conditions are detected, enhancing safety and disaster preparedness.

F) BUZZER

Figure 8: Buzzer

The buzzer is an electronic component that produces sound, commonly used for alerts and signaling in various applications. It operates by converting electrical energy into sound energy, with active buzzers generating sound when powered and passive buzzers requiring an external signal. In the Landslide Detection System, the buzzer provides immediate auditory alerts when potential landslide conditions are detected, ensuring users are promptly informed of risks. Its simplicity and effectiveness make it a crucial component for enhancing safety and responsiveness in emergency situations

G) LED

Figure 9: Led

In a Landslide Detection System, LEDs (Light Emitting Diodes) play a vital role in delivering immediate and clear visual feedback to users. These compact semiconductor devices emit light when an electric current flows through them and are commonly used in electronic systems for signaling and status indication.

H) 9V BATTERY

Figure 10: 9v Battery

In a Landslide Detection System, a 9V battery is commonly used as the primary power source, enabling the system to operate independently in remote or off-grid locations where direct

electrical connections are not available. The use of a battery allows for continuous monitoring of environmental parameters such as soil moisture, vibration, and ground movement, which are critical for early landslide detection.The portability and ease of installation provided by battery power make it ideal for deployment in mountainous or hilly regions that are prone to landslides. A 9V battery is compact, lightweight, and capable of supplying sufficient voltage and current to power low-consumption components like sensors, microcontrollers (such as Arduino),GSM modules (like SIM800L), and alerting devices like LEDs or buzzers.

VI. SOFTWARE IMPLIMENTATION

The software implementation of the Landslide Detection and EarlyWarning System is developed using the Arduino Integrated Development Environment (IDE) and written in C++, a widely used programming language for embedded systems. The Arduino

IDE provides a user-friendly platform with built-in tools for code writing, debugging,and uploading the final program to the Arduino Nano, which is the microcontroller responsible for controlling the system.To facilitate communication with sensors and external modules, several essential libraries are included in the code.

The Wire.h library is used for I2C communication ,which enables the Arduino to interface efficiently with I2C-compatible devices like the ADXL345 accelerometer. The AdafruitSensor.h and AdafruitADXL345U.h libraries are employed to simplify interaction with the accelerometer, allowing for easy reading of tilt and motion data without dealing with low-level register settings.

The soil moisture sensor provides analog readings indicating water content in the soil. If the value crosses a predefined threshold, such as indicating that the soil is near or at saturation, it is flagged as a risk factor. Simultaneously, the vibration sensor is checked for unusual ground tremors or shakes. The ADXL345 accelerometer is queried for changes in angle and orientation across three axes (X, Y,and Z), which can signal ground movement or instability.These sensor readings are then compared against pre- set safety thresholds, determined through calibration and field studies. If any reading exceeds its threshold—or if a combination of risky conditions occurs—the system enters a danger state. In this state, the software triggers multiple alert mechanisms. A buzzer is activated to produce an audible alarm, while LEDs light up to give a visual signal of danger. Additionally, a message is sent through Serial communication, which can be redirected to a SIM800L GSM module to send SMS alerts to emergency contacts or monitoring systems. The modular nature of the software allows for easy expansion and integration with more sensors or cloud-based platforms for advanced data logging and analytics.Furthermore, error handling routines can be embedded to detect sensor malfunctions or communication issues, improving system robustness.

VII. EXPERIMENTAL RESULT

The Landslide Detection and Early Warning System has been successfully developed to monitor critical environmental factors that contribute to landslides. It integrates a soil moisture sensor, SW-420 vibration sensor, and ADXL345 accelerometer, along with a SIM800L GSM module for communication. These components work together to detect excessive moisture, ground movement, and changes in tilt, which are key indicators of potential landslide events.The system operates in real time, continuously collecting and analyzing sensor data using the Arduino Nano microcontroller. When any sensor reading exceeds its threshold, the system activates LED and buzzer alerts, and sends an SMS notification via the GSM module to alert users or authorities, ensuring early .The hardware setup is compact, efficient, and powered by a 9V battery, allowing for autonomous operation even in remote or hilly terrains where power supply is limited. Testing under simulated conditions showed that the system responds reliably and quickly to environmental changes, validating its effectiveness. Overall, this system demonstrates a practical.

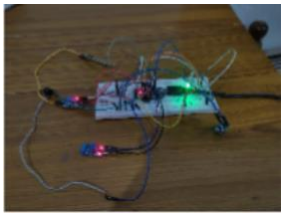

Figure 11:Hardware Setup of the Landslide Detection System

showcases the practical hardware arrangement of the Landslide Detection and Early Warning System. At the heart of the system is the Arduino Nano, a lightweight and reliable microcontroller that reads and processes sensor data in realtime. The system is equipped with essential sensors including the soil moisture sensor for detecting water saturation in the soil, the SW-420 vibration sensor for identifying ground tremors, and the ADXL345 accelerometer for capturing lt or land shifts.These sensors are critical in detecting geotechnical anomalies that signal potential landslide occurrences.During testing, the system consistently monitored environmental changes with high accuracy. When the soil moisture level exceeded the calibrated threshold (indicating soil saturation), or when the vibration and tilt data surpassed safety margins, the system promptly responded by activating the buzzer and LED. Simultaneously, a warning message was transmitted using the SIM800L GSM module,alerting users or authorities about the potential threat.A 9V battery pack powers the entire setup, supporting independent field operation in remote areas where power access is limited. The portable and robust nature of the setup ensures durability under outdoor conditions, making it suitable for long-term deployment. In addition, the system enclosure, which includes protective casing and structured wiring, improves environmental resistance and facilitates easy maintenance.The system was tested under various simulated conditions including increased moisture, slight ground movements,and vibrations. In all cases, the Arduino Nano accurately interpreted the sensor data and responded according to the pre-programmed logic. This confirmed the system's reliability, responsiveness, and practical application in real-world landslide monitoring.Overall, the results validate the functionality of the Landslide Detection System in disaster prevention efforts. It demonstrates how embedded systems and sensor integration can be effectively utilized for environmental risk monitoring,contributing to enhanced safety, timely evacuation, and early warning

capabilities in landslide-prone areas.

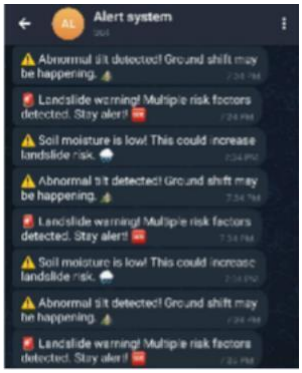

Figure 12: Notification alert of Landslide Detection System

Figure 12: showcases the real-time alert notifications received on a mobile phone through the automated landslide monitoring system. These alerts are generated when sensor values exceed predefined threshold levels, indicating potential risks related to soil instability. The monitoring system continuously collects data from sensors such as the soil moisture sensor, ADXL345 accelerometer for tilt detection, and vibration sensor. Once abnormal values are detected, corresponding warning messages are immediately sent to the user's mobile phone.

VIII. CONCLUSION AND FUTURE SCOPES

The Arduino Nano-based landslide detection system developed in this project stands as a smart, reliable, and cost-effective solution aimed at enhancing safety in landslide prone regions. By intelligently combining a soil moisture sensor, ADXL345 accelerometer,and vibration sensor, the system continuously monitors key environmental indicators that signal potential landslide conditions. Upon detecting abnormal readings
such as excessive tilt, unusual ground vibrations, or critically low moisture levels the system immediately activates visual and audio alerts using a red LED and buzzer.Additionally, the integration of the SIM800L GSM module empowers the system to send real-time SMS alerts to users, ensuring timely warning and remote awareness even in inaccessible areas.This proactive alert mechanism allows communities and authorities to take preventive actions before disaster strikes, significantly reducing risks to life and infrastructure.The project's strength lies in its simplicity, affordability, and ability to operate independently without internet connectivity, making it ideal for deployment in rural and mountainous regions. Moreover, the system offers room for future upgrades such as solar power integration, cloud-based data logging, and mobile app connectivity.In essence, this project demonstrates how low-cost embedded systems can play a transformative role in disaster management and environmental monitoring, promoting safer living conditions and fostering community resilience.

IX. REFRENCES

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A Survey on Automated species classification using YOLO

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Abstract—In marine biodiversity monitoring and conservation efforts underwater species detection plays a pivotal role. This study surveys the implementation of YOLOv8, a state of the art object detection model, fine-tuned using a pretrained FishInv.pt model for real underwater species detection. The dataset consists of 25 marine species, which was manually annotated and split in to training (70was trained on google colab pro with Tesla T4 Gpu, using 100 epochs, a batch size of 16 and to address underwater image challenges such as low contrast and light scattering. Various data augmentation methods and techniques are used. Experimental results show that YOLOv8 was able to achieve a detection speed of 29.3 FPS making the model suitable for monitoring. The model was able to achieve a mean average precision (mAP@50) of 0.812, recall of 0.61 with a precision of 0.94. A comparative analysis with faster R-CNN and YOLOv5 highlights how the superior trade-of between speed and accuracy of YOLOv8 in challenging under water environments helps in the effective detection of species. However, dataset imbalance lead to misclassification, particularly among species which are morphologically similar and related. Future work of the project aims to enhance recall with the help of hyperparameter tuning, advanced dataset expansion, and model optimization for improved computational efficiency. Development of real-time monitoring system, AI powered marine monitoring system was developed supporting ecological research and conservation efforts.

Index Terms—YOLOv8, underwater object detection, deep learning, marine biodiversity, real-time detection.

I. Introduction

Marine biodiversity is crucial for maintaining ecological balance, supporting food chains, and regulating carbon cycles. However, monitoring and identifying marine species has been an ongoing challenge for marine biologists due to the complex and often murky conditions underwater. Visibility issues, water distortion, and occlusions from surrounding objects make it difficult to collect accurate data.

Traditionally, underwater species identification was done manually, relying on divers or remotely operated vehicles (ROVs) for observation. These methods are not only timeconsuming but also prone to human error and subject to limitations of real-time processing. Moreover, they tend to be expensive and inefficient in dynamic underwater environments.

With the advent of artificial intelligence (AI) and deep learning, new approaches to marine species detection have emerged. These methods, based on convolutional neural networks (CNNs), have significantly improved the speed and accuracy of underwater species detection. Among various deep learning models, the YOLO (You Only Look Once) family has become widely adopted due to its efficiency in real-time object detection. YOLOv8, a new version released in 2023, enhances accuracy and speed, making it suitable for real-time applications like autonomous diving and underwater robotics.

This paper explores the application of YOLOv8 in real-time marine biodiversity monitoring, aiming to detect and classify marine species with minimal human intervention. The system developed in this study is based on YOLOv8, trained on a custom-labeled dataset of 25 marine species, and evaluated for precision, recall, and mAP@50.

II. Literature Survey

Laurenz Thomsen [1] This paper displays how AI powered edge computing can be used for real-time species classification which runs on a deep-sea crawler platform as a base using a YOLOv8 model computed on a NVIDIA Jetson Nano. With the help of this model authors where able to achieve a highaccuracy of 0.98, precision of 0.98, and recall of 0.99, all while processing images in 0.31 seconds that also uses only less power con sumption of 0.34 J/image. This paper shows how integrated small AI camera can be used for efficient, automated, precise marine ecological monitoring and protection.. Huimin Lu1,*[2] This paper surveys 40 underwater imaging methodologies featuring enhancements in image descattering, color restoration, and evaluating quality. Fenglei Han, Jingzheng Yao [3] In their research paper, recommends a deep CNN-based framework for underwater image enhancement and object detection. It boosts illuminations mapping using the max-rgb and shades of grey methods after that CNN-based classification is used. The improved CNN model fulfills 90% mAP and 50 FPS, showing its efficiency for real time underwater application. Muwei Jian1,2*† [4] This paper takes a look at 14 traditional and 34 deep learningbased underwater object detection methods. It also inspects 7 representative datasets and talk about 5 key challenges affecting underwater detection such as water turbidity, lighting imbalance and texture deformation providing awareness into future research guidance. Long Chen [5] This paper groups underwater detection methods into different categories like

traditional deep learning and machine learning methods and estimates or analyze their performance across different datasets and talk about different challenges faced like optical distortion and water turbidity and two new detection analysis tools like (diagnosis and TIDE) are used for enhancing model performance. Lijuan Liu1,[6] A broad evaluation of machine learning techniques used in image recognition containing applications such as deep learning-based object detection. Radhwan Adnan Dakhil [7] This paper analyzes different deep-learning techniques used for underwater object detection and enhancement focusing on different applications like marine science, emergency response and disaster prevention. It focuses on key dataset and talk about algorithmic weakness and strengths and identifies research gaps that should be explored in the future in-order to develop more reliable and accurate systems. Xiao Chen [8] This paper brings forth a dual branch feature extraction network called DB-UODN which on combining with ECDB and DSPACSPC to enhance multi-scale feature learning. This model achieves 87.36% accuracy on a dataset called URPC2020 dataset that outperforms existing conventional detection networks. Robert B.Fisher [9] Here 87,000hrs of underwater video is analyzed in a project called fish4knowldedge that detects and study 1.4 billion coral reef fish using ai-based video extracting methodologies. It helps in conducting large scale marine biodiversity and research and it also helps in marine biodiversity conservation. Wenwei Xu [10] Here YOLO object detection model is used for computerized fish detection in underwater videos recording a mAP of 0.5392 across all 3 datasets used in this study. This work emphasizes importance of dataset and proposed enhancements like image augmentation, ensemble models and motion-based observations. Tao Li [11] A deep-learning convolutional model for underwater small object detection is proposed that achieves the highest mAP of 64.1% on UDD and 84.1% on DUO by maintaining low computational complexity. This model is able to surpass latest state-of- the-art advanced models like YOLOv5s and YOLOv8n showing higher accuracy and efficiency. Weiwen Chen [12] A convolutional omni-efficient layer aggregation network (CO-ELAN) and underwater image enhancement module is integrated to YOLOv7 which enhances the model by multifold. Examinations done on URPC2018 shows a 2.4% performance increment by reducing computational cost by 5% displaying increasing in detection accuracy while detecting underwater objects in complex environments. Kun Liu [13] In this paper by integrating transformer selfattention, coordinate attention and capital CLAHE image enhancement with YOLOv5s a model called TC-YOLO is presented which is able to achieve mAP@0.5 of 83.1% and mAP@0.5:0.95 of 45.6 when ran on RUIE 2020 dataset. This is able to strengthen small and dense object detection. Jie Chen [14] In this research paper developed a Dynamic YOLO detector for small underwater object detection by featuring a lightweight backbone, unified feature fusion and an extended decoupled head. It also achieved superior performance of +0.8 AP, Shijia Zhao [15] Here introduced YOLO-UOD which is an improved YOLOv4-tiny variant for real-time underwater detection with less computing power. The model achieved 87.88% mAP using a symmetric bottleneck structure and FPNAttention module thereby balancing speed and accuracy and also specifies a minor speed loss. Zheping Yan [16] Here attention modules and a hybrid image enhancement algorithm for fish detection is combined with CBAM-YOLOv5m based network. Light weight adjustments done here hence reduce network specifications or parameters while continuing high detection accuracy displaying real-time image processing capacity. Qiming Li [17] In this paper a high-resolution feature layer and GEBlock attention module is introduced by YOLOGE which is able to improve small target recognition. This model is able to outperform existing models and methods that is based on datasets such as UTDAC2020, DUO and RUOD which is able to reduce the missed observation and solves positives. Mohammed Yaser Ouis [18] This paper analyzed YOLOv7 and YOLOv8 for underwater species identification with the help of Caltech Fish Counting (CFC) Dataset. YOLOv8 outperformed YOLOv7 with an AP50 of 72.47% vs. 68.3%, discussing the need for fine-tuning YOLO models and specifies need of advanced architectures in underwater detection.Raimondo Schettini and Silvia Corchs [19] This survey investigates underwater image restoration and enhancement methodologies. It discusses problem encountered light scattering, turbidity, and distortion in marine environment images. Fubin Zhang [20] In this research paper CIB building blocks, large-kernel convolutions and partial Self-Attention (PSA) is integrated with YOLOv8 that enhances YOLOv8 model. The enhancements seen are expansion in precision by 2.76% and recall by 2.06% making the new model stronger, for multi-scale object detection and observation. Rashmi Vashisth [21] In this paper image enhancement module and segmentation module for underwater object detection is combined with YOLOv8 based detection framework. It is seen that adaptive histogram equalization technique used here enhances image quality, improving detection precision on different custom datasets used. Djarot Hindarto [22] In this paper with the help of Indonesian fish dataset a YOLOv8 pretrained model is trained and executed which is able to achieve 89.6% detection or precision accuracy that is able to help fisheries to monitor and help in marine biodiversity conservation and able to detect problems faced by marine species. Shenming Q [23] Here Lightweight Efficient Partial Convolution (LEPC) and APFasterNet architecture is combined with YOLOv8-LA that is able to enhance small target detection and register 84.7% mAP at 189.3 FPS. JUE LIU [24] In this study with the help of Dilation-wise Residual (DWR) modules and Inner-SloU loss is able to enhance YOLOv8n which is able to boost detection accuracy by

6.9%, making it more efficient for marine research and observation application.

III. Background and Fundamentals

Marine biological diversity is extremely important to balance ecological diver sity. But observing aquatic species like fishes in water is very challenging and tiring due to complex environmental issues like changes in light, occlusions and limited vis ibility along with huge amount of time required to manually tag each fishes and find its particular species with the help of certain minute details which may not be visi ble to human eyes due to environmental conditions or fast movements. Traditional methods were what scientists depended upon before Artificial intelligence-based ob ject detection models came along. The drawback of those conventional approaches was that they consumed a great amount of human input, which translates to the entire process being slow and labor-intensive. These conventional means of iden tification of marine species, like manual inspection and sonar-based methods, are labor-intensive,frequently useless in changing underwater environments, and above all, costly. This causes distraction from actual marine research and conservation efforts and also places a burden on sanctioned budgets for the project. Recent de velopments in artificial intelligence and deep-learning assist us in creating a more efficient and automated process for underwater object detection. The real-time ob ject detection model created by Ultralytics is YOLOv8, the latest version of ”You Only Look Once.”.It was released in early 2023 and improves upon its predecessors with higher accuracy, speed and efficiency, thus making it suitable for realtime ap plications such as autonomous diving, surveillance and underwater rovers (robotics) and can be processed using edge computing. YOLO (”You Only Look Once”) fa cilitates the rapid and accurate identification of underwater creatures such as fishes including identification of particular species accurately with higher mAP values. YOLOv8 comes with a new backbone network, improved anchor-free detection, and improved scalability on different sizes (Nano to Extra-large). It is popularly known for its balance between ease of use and performance, that favours real-time appli cations like underwater species detection. It also runs efficiently, which means it can also be run in edge computing. Backed by a

strong and active open-source ecosystem and documentation to assist in adding new custom features by the user for detection in specific marine environments .

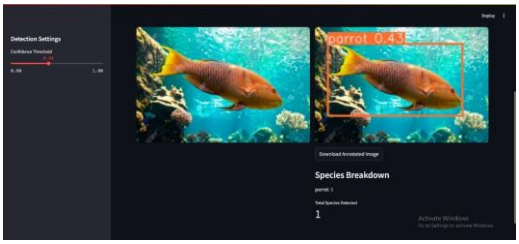

Fig. 1. Species Detection

IV. Taxonomy of YOLO-Based Underwater Detection and Enhancement Research

Recent research on YOLO-based underwater detection and enhancement can be systematically categorized into the following major groups:

A. Foundational Surveys and Comparative Studies

These studies provide comprehensive overviews of existing methodologies and challenges in underwater imaging:

- Lu et al. [2] reviewed 40 enhancement methodologies covering image de-scattering, color correction, and quality evaluation.
- Jian et al. [4] conducted a detailed review of 14 traditional and 34 deep learning-based underwater object detection methods, alongside analysis of 7 datasets and key challenges.
- Chen et al. [5] offered a taxonomy and performance comparison of traditional and deep learning methods using novel analysis tools such as Diagnosis and TIDE.
- Liu et al. [6] provided a broad overview of machine learning techniques for underwater image recognition and object detection.
- Dakhil and Khayeat [7] analyzed various deep learning frameworks, identifying strengths, weaknesses, and research gaps in underwater enhancement and detection.

B. Deep Learning-Based Enhancement and Detection Frameworks

These works propose deep learning models for jointly enhancing underwater image quality and detecting marine objects:

- Han and Yao [3] developed a deep CNN-based pipeline that improves illumination using max-RGB and shades of grey, followed by CNN classification, achieving 90% mAP at 50 FPS.
- Chen et al. [8] proposed a dual-branch network (DBUODN) combining ECDB and DSPACSPC modules, achieving 87.36% accuracy on the URPC2020 dataset.

C. YOLO-Based Fish Detection and Real-Time Systems

These studies specifically utilize YOLO architectures for fish detection and real-time monitoring:

- Xu and Matzner [10] applied YOLO for fish detection, achieving a mAP of 0.5392 across three datasets. The work also discussed the impact of image augmentation and ensemble methods.
- Li et al. [11] presented a lightweight CNN model tailored for small underwater object detection, achieving 64.1% mAP on UDD and 84.1% on DUO, outperforming YOLOv5s and YOLOv8n.
- Ortenzi et al . [1] demonstrated the effectiveness of realtime object detection in ecological data collection with YOLO-based deep learning models on mobile crawler platforms for automatically classifying and counting species in the deep-sea environment.

D. Large-Scale Ecological Monitoring

This category includes large-scale practical applications of AI and YOLO-based models for marine biodiversity studies:

- Fisher et al. [9] led the Fish4Knowledge project, which analyzed over 87,000 hours of underwater video to detect 1.4 billion coral reef fish using AI-driven video processing.

V. Trends and Open Challenges

A. Trends

- Application of YOLOv8 for Real-Time Detection Accurate and high-speed YOLOv8 (e.g., 29.3 FPS, mAP@50 = 0.812) is increasingly used as a real-time baseline model for underwater detection due to its anchor-free model and scalability.
- Edge Computing Integration Implementation on edge devices like NVIDIA Jetson or Coral TPU is fashionable to facilitate low-latency, real-time inspection of remote underwater environments.
- AI-Powered Monitoring Platforms Live web-based platforms for live streaming are being implemented to assist conservationists and researchers with useful data.
- Preprocessing Image Techniques Application of technologies like adaptive histogram equalization, color correction, and noise reduction to correct underwater distortion and visibility.
- Dataset Annotation Tools Massive-scale deployment of tools like Roboflow is being used to annotate custom datasets in order to increase training accuracy and recall.

B. Open Challenges

- Varying Underwater Conditions Light scattering, turbidity, decreased visibility, and color distortion continue to contribute largely to model generalizability and stability across various marine environments.
- Lack of Standardized Underwater Datasets The majority of datasets are small-sized or sparsely annotated and are not easily verifiable cross-platform model.

VI. Comparative Analysis

A. Real-Time Implementation

- Proposed Work: Real-time web interface and video streaming
- Other Works: Mostly offline or no integrated system

B. Dataset Handling

- Proposed Work: 25-class annotated dataset with augmentation
- Other Works: Standard datasets, limited augmentation

C. Error Handling & Robustness

- Proposed Work: Streaming mode, file validation, exception handling
- Other Works: Limited runtime validation

D. Evaluation Metrics

- ProposedWork: Precision, Recall, mAP, FPS, Confusion Matrix
- Other Works: Mostly mAP or accuracy

E. Visualization Tools

- Proposed Work: Real-time display, confusion matrix, dynamic thresholds
- Other Works: Static visuals

VII. Conclusion and Future Scope

The literature survey on YOLO based deep learning techniques and other approaches for underwater species detection shows significant progress in archiving real time detection and high accuracy, stability, making these methods promising in the future when it comes to applications such as marine conservation, ecological monitoring and underwater exploration using autonomous rovers. Studies done in present times shows that performance can be further increased through several new directions that in the past way rarely looked upon. Expansion of dataset, particularly for the species that are rarely detected remains an important factor for enhancing recall metrics and robustness. Challenges like complex occlusions and varying lighting conditions through diverse datasets also has been worked upon in recent works. Model refinement strategies that have been looked upon in the recent research incorporates integrating attention mechanisms like CBAM or Transformer based architecture to enhance feature extraction as well as dynamic confidence

thresholds in varying difficult environments. Also, there is a growing concentration on edge deployment optimizations through innovative techniques like model quantization and pruning, which allows us to enable real time processing using very low power. Optimization on hardware level platforms such as Nvidia Jetson and Coral TPU has been found to allow practical, field-deployable solutions. Future research can explore these strategies thoroughly under greater focus while also exploring hybrid models, domain adaptation techniques and self-supervised learning to enhance generalization in diverse and feature loaded underwater scenarios.

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Event Management System

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Abstract—The Event Management System is a dynamic and innovative platform designed to revolutionize the way events are planned, managed, and executed. The concept of event coordination has evolved over time, transitioning from traditional manual processes to sophisticated digital solutions. This system aims to streamline the event lifecycle, offering seamless registration, automated scheduling, real-time notifications, and intuitive attendee management. With its structured architecture and scalable framework, it ensures a hassle-free experience for both organizers and participants.Developed using modern web technologies, the system leverages React.js for the frontend and Spring Boot for the backend, creating a responsive and interactive user interface while ensuring robust backend processing. The integration of relational databases (MySQL/PostgreSQL) facilitates structured data management, while role-based access control (RBAC) ensures secure and efficient user interactions. Enhancing engagement, the system incorporates automated email/SMS alerts, AI-driven recommendations, and cloud-based data accessibility, allowing for smooth event execution.Security and reliability are at the core of this system, with JWT-based authentication, encrypted transactions, and payment gateway integration enabling secure ticketing and data protection. Designed to minimize manual workload, reduce errors, and enhance collaboration, this Event Management System transforms conventional event planning into a digitally-driven, highly efficient, and user-friendly process. The combination of cutting-edge technology and intelligent automation ensures that events are managed with precision, efficiency, and ease, making it an indispensable tool for modern event coordination

I. Introduction

Event management is a crucial aspect of organizing and executing various types of events, such as conferences, corporate meetings, weddings, and social gatherings. Traditional event planning methods often involve manual coordination, leading to inefficiencies, miscommunication, and time-consuming processes. With the advancement of technology, digital solutions have emerged to streamline event management, improving efficiency and user experience. The Event Management System is a web-based application designed to simplify the process of event planning, organization, and execution. This system enables event organizers to create, manage, and monitor events seamlessly while allowing attendees to register and receive event-related updates. The project is developed using React.js for the frontend, ensuring a dynamic and interactive user interface, and Spring Boot for the backend, which handles business logic, authentication, and data storage. By leveraging a client/server architecture, the system ensures smooth communication between the frontend and backend through RESTful APIs. It also incorporates a relational database like MySQL or PostgreSQL to manage event-related data efficiently. The system provides essential features such as event creation, attendee registration, notifications, and role-based access control, making event management more convenient and automated. This project aims to enhance event organization by reducing manual efforts, minimizing errors, and improving communication between stakeholders. With potential future enhancements such as AI-driven event recommendations, payment gateway integration, and real-time communication features, the system can further improve the overall event management experience.

II. MOTIVATION AND OBJECTIVES

Event management has always been a challenging task, requiring meticulous planning, coordination, and execution to ensure a seamless experience for attendees. Traditional event planning methods, which involve manual registrations, phone calls, emails, and paperwork, often lead to inefficiencies, miscommunication, and scheduling conflicts. With the rapid advancement of technology and digital transformation,there is a growing need for an automated, intelligent, and user-friendly event management system that simplifies the process while enhancing efficiency. The motivation behind developing this Event Management System (EMS) is to provide a centralized, scalable, and efficient platform that automates event planning, improves coordination, and enhances user engagement. By leveraging modern web technologies such as React.js for the frontend and Spring Boot for the backend, the system aims to streamline the workflow, reduce human effort, and minimize errors. The integration of cloud-based services, automated notifications, and secure payment gateways ensures that event organizers and attendees have a hassle-free experience. Moreover, in the post-pandemic era, virtual and hybrid events have gained significant traction, necessitating a robust digital solution that can handle online registrations, real-time updates, and interactive participation. This project is driven by the need to bridge the gap between

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traditional event management and modern technological advancements, making event planning more efficient, secure, and accessible to a wider audience. The Event Management System is designed to streamline the process of event planning and execution by providing an automated, user-friendly, and efficient platform. Traditional event management often involves manual coordination, leading to inefficiencies, scheduling conflicts, and communication gaps. This system aims to address these challenges by offering a centralized digital solution that enables organizers to create, manage, and track events while allowing attendees to register and receive updates seamlessly. By leveraging React.js for the frontend and Spring Boot for the backend, the system ensures a scalable, secure, and responsive experience. The platform integrates key functionalities such as automated notifications, real-time updates, role-based access control, and data management to improve efficiency and minimize human errors. Additionally, it lays the foundation for future enhancements like AIdriven event recommendations, payment gateway integration, and real-time communication features to further enhance user engagement and event success. Key Objectives:

- Automate Event Planning – Reduce manual effort through an interactive platform for event creation and management.
- Enhance Communication – Provide automated email/SMS notifications and real-time updates for organizers and attendees.
- Ensure Scalability and Accessibility – Develop a webbased system accessible from any device with an internet connection.
- . Implement Secure Authentication – Use role-based access control (RBAC) to restrict access based on user roles.
- Optimize Data Management – Store and retrieve eventrelated data efficiently using a relational database.
- Improve User Experience – Offer an intuitive UI with features like search filters, calendar views, and event categorization.
- Minimize Errors and Manual Work – Automate registration, attendance tracking, and scheduling to prevent mistakes.
- Enable Future Expansion – Support AI-based recommendations, payment gateways, and live chat features for better functionality

The Event Management System is designed to be an efficient, scalable, and secure solution that simplifies the event planning process while enhancing user engagement. By integrating modern web technologies and automation, the system reduces manual efforts, improves event coordination, and ensures a seamless experience for both organizers and attendees. The project also lays the foundation for future improvements, making it a robust and future-ready solution for event management

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III. RELATED WORKS

Event Management Systems (EMS) have become essential for efficiently organizing, managing, and analyzing events. In their study, D. A. Shah, H. Vasudavan, and N. F. Razali discuss EMS as digital platforms that streamline event planning, ticketing, attendee management, and feedback collection [1]. These systems integrate features such as automated ticket booking, real-time attendee tracking, digital payment processing, and data-driven feedback collection. The paper highlights that EMS has transformed the event industry by reducing manual efforts, improving efficiency, and enhancing user experiences. Key features of EMS include online registration and ticketing, secure payment processing, attendee engagement tools, and data analytics for event performance tracking. Despite its advantages, EMS adoption faces challenges such as data security risks, technical barriers, and usability concerns. The study also explores advancements like AI-powered automation, blockchain-based ticketing, and augmented reality (AR) for immersive event experiences.The authors conclude that EMS has revolutionized event management by making it more structured and user-friendly. Future developments, including AIdriven automation and enhanced cybersecurity, are expected to further enhance EMS capabilities. This literature review provides valuable insights into how digital tools contribute to a comprehensive EMS, improving event planning, execution, and post-event evaluation. In their review paper, A. Saleem, D. A. Bhat, and O. F. Khan explore the significance of Event Management Systems (EMS) in modern event planning and execution. The study, published in the International Journal of Computer Science and Mobile Computing, highlights how EMS streamlines event organization by integrating various functions such as event scheduling, ticketing, resource allocation, and real-time monitoring [2]. The authors emphasize that the adoption of EMS reduces human errors, enhances coordination among stakeholders, and improves the overall efficiency of event planning. The paper categorizes EMS into different types, including web-based and mobile-based platforms, each offering distinct advantages in terms of accessibility and user engagement. Additionally, it discusses the role of cloud computing in EMS, enabling remote access to event data and facilitating collaboration between organizers and participants. The study also identifies key challenges in EMS implementation, such as security concerns, system scalability, and the need for user-friendly interfaces.

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Furthermore, the authors analyze emerging trends in EMS, such as artificial intelligence (AI)-driven automation, big data analytics for event insights, and IoT-enabled smart event solutions. They conclude that while EMS has transformed event management, continuous technological advancements and improved cybersecurity measures are necessary for its future growth. This review provides valuable insights into the evolution of EMS and its impact on the efficiency and effectiveness of event organization. In the study ”Artificial Intelligence Applications for Event Management and Marketing,”F. Do˘ganay Ergen explores the transformative role of Artificial Intelligence (AI) in modern event planning, execution, and promotion [3]. Published as a chapter in Impact of ICTs on Event Management and Marketing (IGI Global, 2021), the study highlights how AI-powered solutions enhance event efficiency, audience engagement, and data-driven decisionmaking. The author discusses several AI applications in event management, including chatbots for customer service, automated scheduling systems, personalized marketing campaigns, and **predictive analytics for attendee behavior. AI-driven automation minimizes human intervention in repetitive tasks, such as ticketing and registration, allowing event organizers to focus on strategic decision-making. The study also highlights the role of AI in marketing, where machine learning algorithms analyze user preferences to deliver targeted advertisements and optimize event outreach.Furthermore, the paper examines AIpowered analytics tools that process large datasets to provide insights into attendee engagement, sentiment analysis, and event success metrics. AI-driven recommendation engines also personalize event experiences by suggesting relevant sessions, networking opportunities, and content based on user interests. The study acknowledges the challenges of AI adoption, such as ethical concerns, data privacy issues, and the need for skilled professionals to manage AI-driven systems.In conclusion, Ergen emphasizes that AI is revolutionizing event management by making processes more efficient, improving audience interaction, and providing valuable insights through data analytics. The research underscores the growing reliance on AI in the industry and predicts further advancements in AIdriven automation, virtual event experiences, and intelligent decision-making systems for event planning and marketing. P. Arora, M. Gaur, H. Jaisingh, R. Pandey, and T. Rustagi (2023), in their study ”Developing Event Management Web Application”, discuss the development of a web-based EMS designed to automate event planning and attendee management [4]. Their research highlights key functionalities such as online event registration, automated scheduling, ticket generation, and real-time notifications. The study emphasizes that web applications improve event efficiency by providing a centralized platform where organizers can manage multiple event-related tasks seamlessly. The research also explores the use of interactive dashboards and data visualization tools to enhance user experience. R. Kumar, A. Prakash, and M. Bansal (2020) explore the use of blockchain technology for secure and transparent event ticketing [5]. In their paper ”BlockchainBased Event Ticketing System for Secure and Transparent Transactions”, the authors propose a decentralized system that eliminates fraudulent ticketing, unauthorized resales, and data tampering. Blockchain technology ensures that ticket transactions are immutable, verifiable, and tamper-proof, reducing issues such as fake tickets and overbooking. The study demonstrates how smart contracts can automate refund policies and secure ticket transfers while maintaining data privacy for attendees. A. Kumar, S. Gupta, and M. Sharma (2018) focus on cloud computing as a solution for large-scale event management/ [6]. Their paper ”A Cloud-Based Event Management System for Large-Scale Conferences” presents an architecture where cloud platforms provide scalability, flexibility, and real-time accessibility for event organizers. The research highlights that cloud-based EMS reduces infrastructure costs, ensures remote access to event data, and allows for dynamic resource allocation based on demand. The paper also explores real-time data synchronization, which improves attendee engagement and speaker coordination. Similarly, S. Sharma, A. Yadav, and R. Gupta (2020) extend the discussion on cloud-based EMS by incorporating data analytics for improved decisionmaking [7]. Their study, ”Event Management System with Cloud Integration and Data Analytics”, highlights how big data techniques can be used to analyze attendee behavior, optimize event scheduling, and enhance audience engagement. The research demonstrates how predictive analytics can be used to forecast event attendance, suggest personalized event recommendations, and improve marketing strategies.

IV. System Design and Architecture

A. Architecture Overview

The Event Management System (EMS) adopts a microservices-based architecture to ensure scalability, maintainability, and modularity. The architecture consists of the following primary components:

1) Frontend: The user interface is developed using React.js, a modern JavaScript library that facilitates the creation of dynamic and responsive web applications. React.js supports dynamic routing through React Router, enabling seamless navigation between views without full page reloads. The UI is constructed with modular,

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reusable components to enhance code maintainability and ease of updates.

2) Backend: The backend services are implemented using the Spring Boot framework, which provides a robust environment for building RESTful APIs. These APIs encapsulate the core business logic, including event registration processing, user management, and scheduling functionalities. Additionally, the backend manages authentication and authorization mechanisms to secure access to protected resources.
3) Database: Data persistence is handled by a MySQL relational database. MySQL is utilized for storing structured data such as user profiles, event details, registration records, and transaction logs. The relational model supports data integrity and complex querying requirements, while transaction logging ensures accountability and facilitates rollback operations if needed.
4) Security: The system employs JSON Web Tokens (JWT) in conjunction with Spring Security to provide stateless authentication and authorization. Upon successful user login, a JWT is issued and used to authenticate subsequent API requests. This approach enhances security by minimizing server-side session storage and supports scalable deployment.

The modular design of the EMS allows individual components to be developed, deployed, and scaled independently, providing flexibility to handle varying workloads effectively. Furthermore, the architecture supports integration with third-party APIs, including payment gateways, messaging services, and analytics platforms, thereby extending the system's capabilities and enabling future enhancements with minimal disruption.

B. Major Modules

The EMS system is composed of several core modules, each responsible for distinct functionalities and communicating through well-defined APIs to ensure modularity and maintainability:

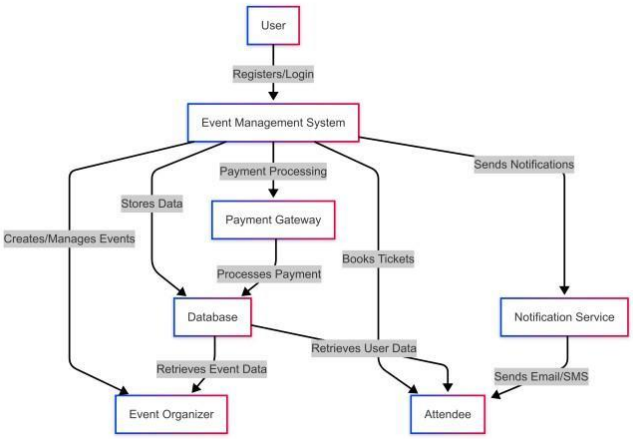

Fig. 1. System Architecture

1) Authentication: This module implements secure user authentication using JSON Web Tokens (JWT). It manages login sessions, token issuance, and validation to protect system resources from unauthorized access.
2) Event Management: Administrators utilize this module to create, update, and delete event information. It maintains event schedules, descriptions, and capacity details, ensuring accurate event lifecycle management.
3) Registration: This module allows users to browse available events and register accordingly. It handles user inputs, registration validation, and stores participant data.
4) Ticketing: Upon successful payment, this module generates tickets for users. It integrates with payment gateways and issues digital tickets that can be verified at event entry points.
5) Notification: Automated notifications are sent via email and SMS to keep users informed about event updates, registration confirmations, and reminders. This module supports communication workflows and ensures timely delivery of alerts.
6) Feedback: After events conclude, this module collects user feedback through surveys. The data is analyzed to assess event success and inform future improvements.

Each module operates independently and interacts with others through RESTful APIs, promoting loose coupling, facilitating debugging, and enabling individual module scalability.

V. Datasets and Workflow

The dataset for an Event Management System includes structured data representing users, events, tickets, payments,

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and other related information. This dataset is crucial for managing event registrations, ticket bookings, payments, and user interactions. Below are the key datasets used in an event management project: The User dataset maintains details of all registered users, including attendees and event organizers, with unique IDs, contact details, and roles. This data is crucial for authentication, role-based access, and personalization. The

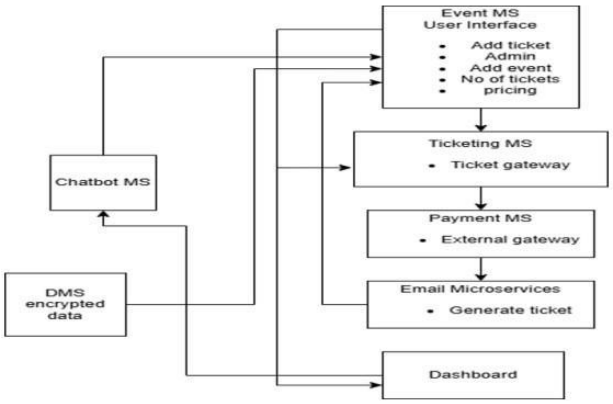

Fig. 2. DataFlow Diagram

Event dataset records all events created on the platform, capturing details like event name, category, location, date, ticket pricing, and availability. This data set helps in managing event listings and tracking upcoming events. The Ticket dataset keeps a record of ticket bookings, linking users to their purchased tickets and tracking ticket statuses, such as confirmed or pending. The Payment dataset manages financial transactions, storing information about payment amounts, methods (such as credit cards or PayPal), and transaction statuses to ensure smooth and secure ticket purchases. The Feedback and Reviews dataset collects user ratings and comments, allowing event organizers to assess attendee satisfaction and improve future events. The Admin System Logs dataset records all system activities, tracking actions like event creation, ticket updates, and payments for auditing and security purposes. Together, these datasets create a structured and efficient system for event management, ensuring seamless user experiences and reliable transaction processing

VI. Implementation Details

The development of the Event Management System begins with the Planning and System Design phase. This stage involves gathering requirements, defining system functionalities, and selecting the appropriate technology stack. Key features such as event creation, ticket booking, payment integration, and user authentication are identified. The system architecture is designed using React.js for the frontend, Spring Boot for the backend, and MySQL/PostgreSQL for database management, ensuring a scalable and efficient structure. During the Development and Implementation phase, the frontend is developed using React.js, incorporating Material UI or Tailwind CSS for a responsive user interface and Redux Toolkit for state management. The backend, built with Spring Boot, consists of RESTful APIs, Spring Security for authentication, and Spring Data JPA for database operations. Payment gateways such as Stripe or PayPal are integrated for secure transactions. This phase follows an iterative approach, ensuring continuous improvements and feature enhancement . The Testing and Security Assurance phase ensures that the system is robust and secure. Unit testing is conducted using JUnit and Mockito, while integration testing is performed using Postman and REST Assured to validate API functionality. The frontend undergoes Jest and React Testing Library tests to ensure a smooth user experience. Additionally, security testing is performed to prevent vulnerabilities such as SQL injection, CORS misconfigurations, and XSS attacks, ensuring data integrity and system security. In the Deployment and Maintenance phase, the frontend is hosted on Vercel, Netlify, or AWS S3, while the backend is deployed on AWS EC2, Heroku, or Docker Containers. The database is managed on AWS RDS or Firebase, ensuring efficient data handling. CI/CD pipelines, implemented using GitHub Actions, Jenkins, or GitLab CI/CD, enable automated deployment and updates. Regular monitoring and maintenance ensure that the system remains functional, scalable, and secure for users.

VII. Results and Evaluation

The EMS was evaluated across multiple critical functionalities to assess performance, security, and user satisfaction:

- Login Functionality: The authentication mechanism demonstrated secure and responsive user logins, effectively safeguarding access through JWT-based token validation.
- Event Scheduling: Administrators were able to create and update events in real-time without noticeable delays, confirming the backend's capability to handle dynamic event management.
- Payment and Ticketing: Payment processing and ticket generation were successfully verified using sandbox environments, ensuring the correctness of transaction workflows and ticket issuance.

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User acceptance testing revealed high satisfaction scores, particularly regarding the system's ease of use and the responsiveness of the user interface design.

VIII. Conclusion and Future Work

In conclusion, the Event Management System built using Java Spring Boot as the backend and React as the frontend successfully achieves the intended objectives of providing a robust, scalable, and user-friendly platform for managing events. By leveraging Spring Boot's powerful REST APIs and React's dynamic, component based architecture, the application ensures seamless communication between the client and server, resulting in a responsive and efficient user experience.The backend, powered by Spring Boot, ensures secure data handling, smooth authentication, and streamlined operations for event creation, modification, and deletion. Meanwhile, the React-based frontend delivers a clean, interactive interface that enhances user engagement and accessibility. The application's modular design also allows for future enhancements, such as integrating real-time features, expanding functionalities, and improving user personalization. Overall, this project demonstrates the effectiveness of combining modern technologies like Java Spring Boot and React to create a full-stack application that meets contemporary standards in web development. Future improvements could include the addition of advanced analytics, improved security measures, and better scalability options to cater to a broader audience.

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COMPREHENSIVE SURVEY ON EEG SIGNAL CLASSIFICATION BASED ON TIME-FREQUENCY ANALYSIS AND MACHINE LEARNING TECHNIQUES

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Abstract—Epileptic seizure prediction and classification are crucial for improving patient care and early intervention. Countless studies have surveyed different machine learning approaches to classify electroencephalogram(EEG) signals into ictal, interictal and preictal. This survey examines a representative methodology that leverages time-frequency feature extraction and supervised learning for seizure state classification. The workflow of this survey begins with the signal preprocessing, include bandpass filtering,channel averaging, and segmentation.Discrete Wavelet Transform (DWT) is used for feature extraction, particularly with Daubechies 4 (db4) wavelet is applied at level 4 decomposition, which effectively captures time-frequency features from signal. The extracted features are typically stored in a CSV file and used to train a random forest model. Labels for training are derived from annotated seizure times. This pipeline demonstrates a robust and interpretable framework for seizure stage classification. By synthesizing such approaches, this survey highlights the potential of time-frequency domain analysis and ensemble learning models in advancing automated seizure detection and prediction systems.

I. Introduction

Electroencephalography(EEG) is a widely used neurophysiological monitoring technique that records electrical activity in the brain. EEG signal classification plays a crucial role in various applications, including brain-computer interfaces (BCIs), seizure detection, mental state analysis, and cognitive research. However, EEG signals are highly complex, nonstationary, and prone to noise, making accurate classification a challenging task. Epilespy is a chronic neurological disorder characterized by recurrent seizures, which are sudden and unprovoked electrical disturbances in the brain. Identifying and classifying different stages of epileptic activity, such as ictal(during a seizure), interictal(between seizure), and preictal(before a seizure), is crucial for effective diagnosis, treatment planning and seizure prediction.

Traditional machine learning (ML) techniques, such as support vector machines (SVM), k-nearest neighbors (KNN), and deep learning models like convolutional neural networks (CNNs) and recurrent neural networks (RNNs), have been widely adopted for EEG classification. These models relay on extensive feature extraction and labeled datasets for supervised learning.

This survey mainly focused on classifying the EEG signal is a hybrid methodologies that combines time frequency features and annotated seizure timings in the dataset. Discrete Wavelet Transform (DWT), particularly using Daubechies wavelets, are frequently used to capture the dynamic frequency content of EEG signals across multiple temporal scales. These extracted features, when paired with robust classifiers like Random Forests, have yielded high classification accuracy in distinguishing epileptic stages. This survey aims to provide a focused overview of such methodologies, highlighting the effectiveness of time-frequency feature extraction and ensemble learning models in seizure state classification.

By recording the electrical activity of the brain, electroencephalography (EEG) is still a vital diagnostic and monitoring tool for epilepsy. Traditional manual interpretation of EEG data, however, is frequently time-consuming, labor-intensive, and subject to subjectivity. The automated classification of EEG signals, which provides reliable, impartial, and effective analysis for seizure detection and prediction, has drawn more attention from researchers in an effort to get around these restrictions. The complexity and variability of epileptic patterns, noise and artifacts in EEG recordings, and the need for efficient feature extraction and selection are some of the obstacles that automated EEG classification must overcome despite its potential. As a result, a range of computational approaches have been investigated, from complex signal processing techniques and ensemble learning strategies to traditional machine learning algorithms. These methods seek to improve clinical decision-making, encourage real-time monitoring, and increase classification accuracy. In order to increase real-world applicability, current research efforts focus on creating strong classification frameworks, using suitable evaluation metrics, and looking into preprocessing and feature engineering techniques. All things considered, automated EEG signal classification has become a crucial field of research for improving seizure management and epilepsy diagnosis.

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Wei Zhang, Xianlun Tang1 and Mengzhou Wang[1] This research examines how brain-computer interfaces (BCIs) utilize EEG signals to control devices, focus on advanced signal processing and machine learning for accurate seizure detection.Muhammad Haseeb Aslam 1, Syed Muhammad Usman[2] It enhances accuracy and computational efficiency by focusing on key signal features, making it particularly suitable for real-time BCI applications and seizure prediction. Hafeez Ullah Amin, Wajid Mumtaz[3] The work is concerned with EEG-based brain-computer interfaces by employing machine learning and pattern recognition to enhance brain signal classification. Feature extraction and real-time monitoring are highlighted in order to increase accuracy for clinical as well as assistive applications such as diagnostics and neurorehabilitation. Maria Camila Guerrero, Juan Sebasti an Parada[4] The study aims to compare four machine learning models, logistic regression, ANN, SVM, and CNN, to classify EEG signals in being an epileptic or non-epileptic state. It highlights that EEG signals features are Fourier-based and that ANNs had the highest accuracy (86%) which can help produce reliable EEG signal-based diagnostics. Prasath, A.S.S, Lokesh[5] This article discusses machine learning and deep learning methods- such as logistic regression, ANN, SVM, and CNN- for the classification of EEG signals that use Discrete Wavelet Transform for feature extraction, and provides a comparative performance assessment with recommendations as to which models were most likely to accurately diagnose EEG data. Mohammed Yousif, Iman Ameer Ahmad[6] The paper offers a new classification method for EEG data using modified DWT for feature extraction, Gray Wolf Optimization for feature selection, and a hybrid SVM-NN model for classification. The authors achieved 97% accuracy, and it offers a reliable method for BCI applications and neurological diagnostics. Also, it aligns well with the EEG preprocessing and classification requirements of your project. Swati Chowduri, Satadip Saha Samadrita Karmakar[7] This article describes a real-time EEG classification system for use on portable devices that utilized machine learning to monitor student attitional engagement. Author's description of real-time data processing, model resampling, temporal interpolation and model deployment, as well as educational applications may provide useful insights when developing your responsive BCI or neurofeedback systems. Hepseeba kode, Khaled Ellety[8] The article discusses machine and deep learning methods for detection of epileptic seizures with EEG signals, emphasizing relevant feature extraction processes (e.g. wavelet transforms) and rigorous performance evaluation. It provides a brief overview of the most relevant methods for building real-time seizure detection systems that accurately detect seizure events with good performance applicable to your project goals. Remy Ben Messaoud, M Chavez[9] A strong machine learning approach using a Random Forest model and handcrafted features is proposed in the paper to predict epileptic seizures from EEG data. The proposed method is evaluated on the CHB-MIT and Kaggle datasets and exhibits strong performance because of a high accuracy (up to 89.31% sensitivity and 0.03/h false positive rate) due to careful preprocessing, feature extraction, artifact rejection and a new alarm-raising method. The paper argues the importance of methodological rigor and personalization for producing results that are clinically relevant for real-time prediction of seizures. A. T. Tzallas, M. G. Tsipouras, and D. I. Fotiadis[10] Using time-frequency (T-F) analysis methods like Cohen's class distributions and the Short-Time Fourier Transform, this paper suggests a way to identify epileptic seizures in EEG signals. Using artificial neural networks, it classifies EEG segments and extracts energy-based features from the time-frequency plane, achieving high accuracy on a variety of classification tasks. Z. Iscan, Z. Dokur, and T. Demiralp[11] In order to classify EEG signals, this paper combines frequency-domain features extracted using power spectral density (PSD) with time-domain features obtained from cross-correlation. Using a benchmark epileptic EEG dataset and Least Squares Support Vector Machines (LS-SVM), the study shows that combining both feature types greatly increases classification accuracy, reaching up to 100% accuracy. D. Gajic, Z. Djurovic[12] This study investigates an automated method of identifying epileptic activity in EEG signals by combining wavelet, time, frequency, and non-linear analysis features, such as Lyapunov exponents. They use a quadratic classifier to classify the features after reducing their number using scatter matrices. M. Yousif, I. A. Ahmad [13] A hybrid method for categorizing EEG signals is presented in the paper. Wavelets are used to extract features, Gray Wolf Optimization is used to select the best features, and a combination of SVM and neural networks is used for classification. It outperforms many other models with an accuracy of 97% on EEG data associated with language tasks. M. Musselman and D. Djurdjanovic [14] With the help of binary SVM subproblem modeling, class-specific feature selection, and features taken from bilinear time-frequency distributions of EEG signals, this paper suggests a novel epilepsy classification algorithm. The technique demonstrates consistent accuracy across different training data proportions and outperforms current methods on benchmark data. K. Samiee, P. Kovacs [15] A novel Rational Discrete Short-Time Fourier Transform (DSTFT) for adaptive, localized time-frequency feature extraction from EEG signals is used in this paper to present an epileptic seizure detection system. The method outperforms several state-of-the-art techniques in terms of accuracy and compactness of EEG representation. A multilayer perceptron is used to classify the extracted features. A. T. Tzallas, M. G. Tsipouras [16] In this work, time-frequency (TF) analysis and artificial neural networks (ANNs) are used to automatically identify epileptic seizures in EEG signals. The method outperforms current techniques on a publicly available dataset by extracting features from TF representations of EEG segments and classifying them with high accuracy (up to 100% in some cases).

T. Tzallas, M. G. Tsipouras, and D. I. Fotiadis [17] This study presents a novel technique that uses artificial neural networks (ANNs) and time-frequency (TF) analysis to identify epileptic seizures in EEG recordings. The method achieves high classification accuracy (up to 100% in some cases) across various seizure detection scenarios by extracting features from TF distributions to represent EEG energy patterns. In order to show how effective different TF distributions are for automated seizure detection, the study compares them. [18] The Hilbert-Huang Transform (HHT), which combines the Hilbert Transform and Empirical Mode Decomposition (EMD) to extract instantaneous frequency and amplitude features, is used in this paper to classify seizure and non-seizure EEG signals. The suggested method outperforms conventional methods like Multivariate EMD in separating epileptic seizures from normal brain activity, achieving high accuracy (94%) and specificity (96%) in the process. The tool is praised for its affordable price, easy-to-use interface, and real-time applicability. K. K. Dutta, P. Manohar [19] This study uses raw EEG signals from three datasets: Freiburg Hospital (FH), CHB-MIT, and Temple University Hospital (TUH) to propose a convolutional neural network (CNN)-based method for classifying epileptic seizure stages (preictal, ictal, postictal, and interictal). The model shows promise for automated seizure stage detection without preprocessing by achieving high accuracy (up to 94.02% for TUH) in binary and multi-class classification. The study demonstrates how well CNN handles unprocessed EEG data, providing a useful tool for patient monitoring and clinical diagnosis. M. Naeem, S. T. H. Rizvi [20] A thorough introduction to Reinforcement Learning (RL) is given in this paper, which covers basic ideas such as Markov Decision Processes (MDPs), important RL algorithms (such as Q-learning, SARSA, and Actor-Critic), and their uses in a variety of industries, including computer vision, robotics, healthcare, and the Internet of Things. It is a useful tool for both novices and researchers because it also covers issues and potential paths in reinforcement learning.

II.OBSERVATIONS

A. *Time-Frequency Analysis is Highly Effective for Seizure Detection*:

In EEG-based seizure detection, time-frequency (T-F) representations have become extremely effective tools. Numerous studies [10], [16], [17] highlight how well techniques like the Short-Time Fourier Transform (STFT) and Cohen's class distributions capture non-stationary patterns linked to epileptic episodes. When paired with Artificial Neural Networks (ANNs), these T-F features have shown remarkable performance, attaining classification accuracies of up to 100% [10], [16], [17]. Additionally, Rational Discrete STFT (DSTFT), which was first presented in [15], offers a localized and adaptive T-F representation that outperforms conventional T-F techniques and yields a more condensed and informative EEG characterization.

B. *Hybrid Feature Extraction & Selection Improves Performance:*

Because wavelet-based techniques can analyze EEG signals on a variety of scales, they still dominate feature extraction. Particularly in seizure classification tasks, Discrete Wavelet Transform (DWT) has demonstrated impressive performance [5], [6], [8], [12], [13]. Studies such as [6], [13] report up to 97% accuracy when DWT is coupled with metaheuristic feature selection algorithms like Gray Wolf Optimization (GWO). In addition to wavelets, hybrid feature sets that incorporate nonlinear dynamics (like Lyapunov exponents), time-domain, and frequency-domain (like power spectral density) have been shown to improve classification robustness [11], [12]. Furthermore, the Hilbert-Huang Transform (HHT) has been investigated for the extraction of instantaneous frequency features; its 94% detection accuracy [18] demonstrates its potential for capturing dynamic, complex signal behaviors.

C. *.Machine Learning Models Perform Well, but Deep Learning is Emerging:*

Seizures can still be detected using conventional machine learning models. Because of their interpretability and resilience, Random Forest (RF) and Support Vector Machines (SVM) are extensively used. For example, [9] uses handcrafted features with RF to achieve 89.31% sensitivity and a low false alarm rate, while [14] uses a binary SVM with class-specific feature selection to increase generalizability. But deep learning techniques are becoming more popular, especially for end-to-end EEG classification. When it comes to multi-class seizure stage classification, Convolutional Neural Networks (CNNs), as employed in [19], can process raw EEG directly without the need for preprocessing, attaining 94.02% accuracy. According to comparisons in [4], [5], ANNs can achieve up to 86% accuracy, outperforming traditional models like logistic regression and SVMs.

D. *Real-Time Applicability & Clinical Feasibility:*

A focus on real-time applicability is necessary when converting research models into clinically feasible solutions. The significance of low-latency processing and realistic implementation in seizure prediction systems is emphasized in works like [7], [9], [18]. Notably, [18] highlights accessibility and efficiency by showcasing an affordable, user-friendly system built on HHT. The system's clinical relevance is further enhanced by alarm-triggering mechanisms added in [9], which facilitate prompt intervention. Furthermore, research [15], [16] emphasizes the computational effectiveness of T-F analysis techniques,

making them viable options for incorporation into real-time brain-computer interface (BCI) systems.

III. CONCLUSION & FUTURE SCOPE

For EEG-based seizure classification, the reviewed research papers show that time-frequency (T-F) analysis in conjunction with machine learning (ML) and deep learning (DL) models is very effective. While models like Support Vector Machines (SVM), Random Forest (RF), Artificial Neural Networks (ANN), and Convolutional Neural Networks (CNN) achieve high accuracy (up to 100% in some cases), Techniques like Short-Time Fourier Transform (STFT), Wavelet Transforms (DWT), and Hilbert-Huang Transform (HHT) offer robust feature extraction. Performance is further improved by hybrid techniques, such as wavelet-based feature extraction combined with Gray Wolf Optimization (GWO) for feature selection. Furthermore, it is possible to develop real-time seizure detection and prediction systems; some studies have included effective preprocessing and alarm mechanisms for clinical implementation.

Notwithstanding these developments, there are still issues with computational effectiveness, generalization across various EEG datasets, and reducing false alarms in practical applications. To further enhance seizure detection systems, future studies should investigate automation and adaptive learning.

Proximal Policy Optimization (PPO) and Hierarchical RL are two sophisticated reinforcement learning (RL) approaches that should be investigated in future automated seizure classification research to improve adaptability in dynamic EEG environments. Lifelong learning from streaming EEG data can be achieved through self-supervised pre-training and continuous reinforcement learning, and federated RL frameworks may allow for multi-institutional cooperation without jeopardizing patient privacy. Optimizing lightweight RL models (like quantized DQN) for edge devices will be crucial for real-world deployment. Furthermore, clinical trust can be enhanced by combining RL with explainable AI (XAI) techniques like uncertainty estimation and attention mechanisms. Lastly, hybrid neuro-symbolic techniques that integrate RL with domain expertise could improve the interpretability and accuracy of seizure prediction.

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Procedural Generation of 2D World

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I. ABSTRACT

Procedural generation refers to the automatic creation of content using algorithms and mathematical models, instead of crafting each element manually. In the context of 2D games, this technique is widely used to generate expansive and dynamic game environments such as terrain, caves, maps, and dungeons. The goal of this mini project is to design and implement a system that can procedurally generate a 2D world using various algorithmic approaches, thereby enhancing both the efficiency of game development and the variability of gameplay experiences.

This project utilizes procedural generation techniques such as Perlin Noise for smooth terrain heightmaps and Cellular Automata for natural cave structures. These algorithms help create visually appealing and organically distributed worlds, ensuring each game session feels fresh and unique. Additionally, the implementation supports features such as seed-based generation, allowing for reproducibility of worlds, and modular tile assignment, enabling customization of environments.

Developed using the Unity game engine and C, this system demonstrates how procedural techniques can significantly reduce manual design work while offering infinite possibilities in world-building. It opens up potential applications in various genres like roguelikes, survival games, and open-world exploration titles.

Through this project, we explore the balance between randomness and control in level design and highlight how procedural content can be both an artistic and technical asset in modern game development.

II. INTRODUCTION

Procedural generation (PG) is revolutionizing game development by enabling the creation of dynamic, endlessly replayable environments with minimal manual effort. Unlike traditional level design, which relies heavily on hand-crafted layouts and assets, PG allows developers to algorithmically generate content that adapts to player interactions and gameplay context. This approach significantly reduces development time while introducing unpredictability and variety into the gaming experience.

In the realm of 2D games, PG proves particularly effective. Side-scrolling and top-down games benefit greatly from the ability to spawn infinite levels, introduce random hazards, and modify environmental features in real time. Games like Flappy Bird, Jetpack Joyride, and countless roguelikes have popularized this approach, using procedural systems to maintain challenge and replayability across repeated sessions. This project builds on that foundation by implementing a general-purpose procedural generation framework tailored for 2D games, developed using the Unity engine for rapid prototyping and cross-platform support.

The framework is capable of generating Flappy Bird-style pipe obstacles, crafting continuous scrolling roads with dynamically inserted traffic and hazards for car games, and exposing an intuitive interface for game designers to tweak core generation parameters. This interface supports control over frequency, obstacle spacing, difficulty scaling, and more, allowing for a balance between randomness and playability. The goal is to provide a flexible system that works across different game types while remaining easy to configure and extend.

To achieve this, a blend of procedural algorithms is used. Perlin noise introduces natural variation in terrain and obstacle spacing, producing smooth, non-repetitive patterns. Cellular automata simulate emergent complexity in environmental features or obstacle clusters, making the world feel more alive

and organic. Random walk algorithms are employed to create winding paths and unpredictable layouts in driving levels or maze-like structures. Wave Function Collapse (WFC), a constraint-satisfaction algorithm, assembles tile-based worlds based on a sample input, ensuring that generated environments remain coherent and visually appealing.

Unity's game engine provides the perfect environment for this system, offering real-time rendering, a powerful component system, and editor support for parameter tuning. Through Unity's scripting tools, generation logic is integrated with gameplay mechanics, while visual debugging tools like gizmos and custom inspectors help visualize and adjust the output of the algorithms during development. ScriptableObjects store presets for easy reuse and sharing, while coroutines enable smooth runtime generation without disrupting gameplay.

The resulting system supports a wide range of 2D games, from infinite runners and arcade-style driving games to roguelike dungeon crawlers and platformers. Designers can quickly prototype and iterate on level ideas without having to place each obstacle manually, and players benefit from the unpredictability and freshness each new session brings.

Looking ahead, this procedural system offers a foundation for further innovation. Potential future work includes integrating adaptive difficulty through player behavior analysis, synchronizing PG for multiplayer environments, or layering in thematic variation through biome rules. As procedural generation continues to evolve, its integration into game design will become increasingly sophisticated, pushing the boundaries of what's possible in interactive digital worlds.

III. Literature survey

Risi and Snodgrass (2018) explore the use of Generative Adversarial Networks (GANs) for procedural content generation (PCG). Their research demonstrates how deep learning models can learn from existing game levels and generate new ones with similar structural patterns. By training a GAN on curated datasets, the study highlights the potential of AI-driven PCG to create high-quality and diverse game environments without explicit rule-based systems. The paper emphasizes the advantages of using deep learning in procedural generation, particularly in automating level design while maintaining creativity and coherence.[1] Shaker (2016) investigates tile-based procedural level generation using genetic algorithms. The study applies evolutionary techniques to optimize tile placement, ensuring that generated levels adhere to design constraints while maintaining variety. By using fitness functions to evaluate level quality, the approach enables automated level generation that balances challenge and playability. The research showcases how genetic algorithms can effectively generate structured yet diverse game levels, making them a viable alternative to traditional rule-based methods.[2] Gumin (2019) presents the Wave Function Collapse (WFC) algorithm for 2D world generation, a technique that constructs game environments based on constraint satisfaction. The study explains how WFC analyzes input patterns and generates new content that adheres to predefined constraints, ensuring coherence in generated worlds. The paper highlights the efficiency of WFC in creating structured, visually consistent maps and textures while maintaining a degree of randomness, making it a powerful tool for procedural content generation in games.[3] Cook and Smith (2015) explore procedural map generation using cellular automata, focusing on how local interactions between cells lead to emergent structures. Their research demonstrates how simple rule-based systems can produce complex and natural-looking game environments, particularly in terrain and cave generation. The study highlights the flexibility of cellular automata in generating dynamic and varied landscapes, showcasing its effectiveness in creating immersive and organic game worlds.[4] Doe (2007) explores procedural modeling through graph grammar, a technique that represents game environments as graph structures where transformation rules dictate content generation. This approach allows for structured and scalable procedural 4 Procedural generation of 2d world generation, ensuring that game worlds maintain logical consistency while offering variety. The study highlights the benefits of using graph grammar in creating complex, interconnected environments, particularly in games that require structured progression or modular design.[5] Smith (2023) introduces the nested wave function collapse algorithm, an extension of the traditional wave function collapse method. This approach enhances procedural generation by incorporating hierarchical constraints, allowing for more detailed and structured content creation. The paper emphasizes how nesting enables a balance between randomness and controlled structure, making it particularly useful for generating game maps, architecture, and terrain while maintaining coherence in the generated content.[6] Johnson (2022) examines procedural dungeon generation using binary space partitioning (BSP), a method that recursively divides space into smaller sections to create structured yet diverse dungeon layouts. This technique ensures that the generated levels have a logical flow while maintaining variety in room placement and connectivity. The study demonstrates how BSP can be efficiently implemented to generate dungeons that offer engaging gameplay experiences with well-defined pathways and challenges.[7] White (2020) explores the use of cellular automata in 2D procedural generation, leveraging rule-based systems to create organic and diverse game environments. The research focuses on how local interactions between cells can result in emergent patterns that mimic natural formations, such as cave systems or terrain structures. The paper highlights the effectiveness of cellular automata in generating dynamic and visually appealing game worlds, particularly in genres that benefit from irregular, natural-looking environments.

IV. Motivation

Manual level construction restricts variety and hampers scalability. PG allows developers to concentrate on core mechanics and narrative while the algorithm populates the world. For players, every run feels fresh, sustaining engagement and extending a game's lifespan.

Procedural techniques also reduce memory usage, since entire worlds can be generated from a small set of rules or noise functions. This is especially valuable in mobile or resource-constrained platforms. Additionally, PG introduces an element of surprise and discovery, which is hard to replicate with hand-crafted content.

From an educational standpoint, building procedural systems deepens understanding of algorithms, randomness, and spatial logic. It bridges the gap between theory and practice, demonstrating how code can create complex, replayable content with minimal input. This project aims to explore that balance between control and chaos in a 2D space.

Moreover, procedural generation enhances the **replayability** of games by ensuring that no two sessions are exactly alike. This is critical for games like roguelikes, endless runners, and sandbox experiences where variability drives long-term interest. For developers, it reduces repetitive design work while increasing the creative scope of what can be delivered to the player.

This mini project was also motivated by the desire to simulate real-world-like unpredictability and variety within a simple 2D environment. Algorithms like Perlin noise and cellular automata can mimic natural formations like mountains, caves, or roads, offering a unique opportunity to combine algorithmic precision with artistic freedom.

Ultimately, the project provides a hands-on opportunity to merge theoretical knowledge of computer science—such as data structures, AI logic, and optimization techniques—with real-world game development challenges using tools like Unity and C#.

V. Objectives

The primary objective of this project is to explore and implement procedural generation (PG) techniques for dynamically creating 2D game environments. Procedural generation has become a powerful tool in modern game development, enabling the creation of varied and complex content using algorithms instead of manual design. This project focuses on demonstrating how procedural content generation can be applied effectively to both side-scrolling and top-down 2D game genres.

By combining algorithmic logic with design constraints, we aim to generate game levels that are not only different on each run but also balanced in terms of difficulty and performance. This includes the use of Perlin noise for terrain shaping, cellular automata for natural structures like caves, and randomized spawning systems for obstacles.

a) Key Objectives::

1) **Develop a Generalized Procedural Generation Algorithm** – Design and implement a reusable and modular algorithm capable of generating content for various 2D games. This includes generating tiles, obstacles, terrain features, and level structures that follow both random and rule-based patterns.
2) **Implement Procedural Spawning in Flappy Bird** – Replace static pipe placement with a dynamic spawning system that adjusts pipe positions based on time or distance. This ensures each playthrough is unique and engaging, without compromising fairness.
3) **Apply Procedural Generation in a Car Game** – Create an endless or looped road layout using procedural logic to generate roads, turns, traffic obstacles, and environmental details in a top-down racing/driving game. The focus is on maintaining challenge, variety, and performance.
4) **Optimize Performance and Playability** – Maintain smooth frame rates and responsive gameplay by ensuring that the generated content does not overwhelm system resources. Balance randomness with deterministic rules to prevent impossible or unfair level configurations.
5) **Enhance Knowledge in Game Development** – Strengthen technical skills in Unity game development, C# scripting, and game algorithm design. Gain practical experience in working with tilemaps, object pooling, random number generation, and spatial data structures.
6) **Encourage Replayability and Engagement** – Improve player retention by ensuring that each game session feels fresh and unpredictable, encouraging users to replay the game multiple times.
7) **Lay the Groundwork for Future Enhancements** – Provide a foundation that can support advanced features in the future, such as AI-generated levels, adaptive difficulty, player progression tracking, and multiplayer PG synchronization.

VI. Related Work

Early work in procedural generation (PG) focused primarily on simple algorithms like noise functions and cellular automata, which could produce organic-looking terrain and cave systems. Over time, the field evolved, incorporating advanced AI and data-driven techniques to produce more structured and coherent results.

- **Risi & Snodgrass (2018)** – This study introduced the use of Generative Adversarial Networks (GANs) for level generation in games. The GAN was trained on existing level data to generate new layouts that resemble the original design patterns. This approach brings high visual coherence but requires large datasets and training time.
- **Shaker (2016)** – Explored the use of genetic algorithms for generating tile-based platformer levels. By evolving candidate solutions based on fitness functions (such as playability and difficulty), this method introduces adaptive content evolution but can be computationally intensive.
- **Gumin (2019)** – Developed the popular *Wave Function Collapse (WFC)* algorithm, which uses constraint-based logic to tile 2D space without violating adjacency rules. This method achieves a high level of control over local and global structure, making it suitable for puzzles, dungeons, and architectural environments.

- **Cook & Smith (2015)** – Investigated cave generation using cellular automata. This method simulates natural processes like erosion or growth by iterating over binary grids, creating believable and organic cave systems with minimal input.
- **Johnson (2022)** – Implemented binary space partitioning (BSP) for dungeon generation. BSP recursively splits the map space into subregions, which are later converted into rooms and hallways. This technique is widely used in roguelikes due to its simplicity and effective layout generation.

These foundational studies reveal an inherent trade-off between randomness and structure. Fully random approaches generate high variety but often lack coherence or playability. Structured or rule-based approaches (like WFC and BSP) offer consistency but may reduce novelty. AI-driven methods (e.g., GANs, genetic algorithms) attempt to bridge this gap by learning patterns from data or evolving designs over time.

VII. Proposed System

A. Problem Statement

Hand-crafted levels limit diversity. The challenge is to generate endless but *playable* worlds in real-time without overwhelming device resources or the player.

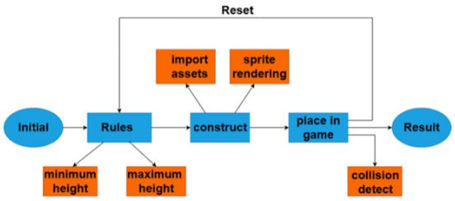
B. System Outline

- **Pipe Spawner** – instantiates pipe prefabs at timed intervals; vertical offset chosen via `Random.Range` with clamped bounds.
- **Road Generator** – uses segment prefabs; a Markov-style controller selects the next segment (straight, curve, intersection) based on context.
- **Obstacle Injector** – places hazards (cones, other cars) according to distance travelled and current speed.
- **Difficulty Controller** – gradually tightens pipe gaps or increases traffic density.
- **Cleanup Module** – destroys off-screen objects to reclaim memory.

C. System Architecture

1. Design and Import Game Assets Develop 2D game assets (characters, back grounds, obstacles, UI) using software such as Photoshop, Illustrator, Aseprite, or GIMP. Pixel art for retro games, vector art for HD games. Save assets as PNG (transparency) or SVG (scalable). Import into Unity: Drag assets into Assets folder and choose Texture Type → Sprite (2D and UI). Sort assets into folders (Sprites, Animations, UI, Sounds).
2. Use It With Sprite Renderer The Sprite Renderer renders 2D images in Unity. Steps: GameObject → Add Sprite Renderer. Drag a sprite into the Sprite box. Key Properties: Sprite: Shows the image. Color: Tints the sprite. Flip X/Y: Reverses image direction. Sorting Layer Order: Determines sprite overlap. Optimization: Use Sprite Atlases (sprite sheets) to minimize draw calls. Minimize transparency effects for performance.
3. Add Collider to the Object A Collider provides physics interaction and collision detection. Steps: GameObject → Add Collider (Box, Circle, Polygon, Edge). Edit size and position in the Inspector. 2D Colliders used commonly: Box Collider 2D: For flat platforms and stationary objects. Circle Collider 2D: For spheres. Polygon Collider 2D: For irregularly shaped objects. Edge Collider 2D: For edge of terrain. Key Property: Is Trigger: Allows event sensing without object obstruction.

SYSTEM ARCHITECTURE



System Architecture Diagram

VIII. TECHNICAL DETAILS

- Procedural generation of a 2D game is a method in which content for the game, like terrain, obstacles, enemies, and levels, is generated using algorithms rather than being hand-designed. Unity is a cross-platform game engine that can be used for both 2D or 3D game de velopment and supports advanced functionality for physics, rendering, and scripting in C sharp.
- Unity mostly uses C sharp as the scripting language to enable game developers to be capable of applying game mechanics, physics, animation, and user input in a more effective manner Where We Use These Methods:
  Terrain Generation: Perlin Noise is used to generate natural terrain such that the terrain would experience smooth height changes
  .Obstacle and Enemy Placement: Random Walk assists in the dynamic placement of obstacles and enemies and keeps the level of difficulty in balance.
  Level Design: Markov Chains assist in designing well-organized levels with a sensible sequence, creating variety without randomness turning into chaos.
  When We Use These Methods:
  At Game Launch: The game world is dynamically created prior to the player's commencement of play.
  In Gameplay: New parts of the game world are constructed as the player advances, hence becoming an endless experience.
  When Replayed: A new and varied game world is created each time, making it replayable.

A. *Collider*

Colliders are used within Unity to determine the physical shape of an object so that detection of collisions becomes possible. Colliders in procedural generation prevent procedurally generated obstacles and terrain from getting in the way of the player and other objects. BoxCollider2D

is used with pipes in Flappy Bird and PolygonCollider2D for complex road obstacles within the racing game.

B. *Spriterenderer*

SpriteRenderer is a Unity component for rendering 2D sprites. SpriteRenderer is used to visually represent procedurally generated objects such as pipes, road seg ments, and obstacles. Modifying the properties of the sprite such as size and color ensures visual variety in the procedurally generated world.

C. *Prefab*

Prefabs are reusable Unity game objects made up of components, setups, and scripts. Prefabs are dynamically created when procedural generation occurs to create ob stacles, patches of terrain, and other objects without the need to create each one manually. It is more manageable and more efficient as a consequence.

D. *Rigidbody*

The Rigidbody2D game object component adds the physics-based movement and interaction to the game objects. Rigidbodies are used in procedural generation to handle player movement, gravity forces (Flappy Bird's fall), and object dynamics (steering vehicles or obstacles). Control of these parameters as mass, drag, and constraints allows the natural and proper physics behavior on the game.

IX. Experimental Results

Tests were performed on a mid-range laptop (Intel i5-1135G7, 8 GB RAM, Iris Xe).

TABLE I
PERFORMANCE BENCHMARKS

Scenario	Avg FPS	Peak Memory
Flappy-style, 10 active pipes	60 fps	140 MB
Flappy-style, 50 active pipes	57 fps	165 MB
Car game, 5 road segments	60 fps	150 MB
Car game, 20 segments + traffic	55 fps	185 MB

Difficulty curve: Average survival time was 6 min (Flappy) and 8 min (car). Players reported a fair but challenging progression.
Replayability: Ten successive runs produced unique layouts each time, confirming high variability.

X. Future Work

1) Integrate official APIs (e.g., Steam Workshop) for player-authored levels.
2) Extend algorithm to 3D environments with height-maps and procedural meshes.
3) Introduce AI-assisted level critique to auto-flag impossible layouts.
4) Package as a Unity plug-in with custom editors for designers.

XI. Conclusion and Future scope

A procedural generation engine for a 2D world creates dynamic and diverse game environments, enhancing replay value by automatically generating terrain, obstacles, and other gameplay elements. This approach not only reduces the workload on designers but also brings scalability and variety to the gameplay experience. By leveraging algorithms such as Perlin Noise and tile-based generation, the system ensures varied and unpredictable gameplay experiences across multiple sessions, without sacrificing performance or game balance.
This project has successfully implemented procedural generation in two distinct gameplay contexts:

- **Flappy Bird-style Obstacle Generation:** Obstacles are spawned dynamically based on player progress, with randomized gaps and positions. This ensures that each run feels unique, yet fair, with difficulty scaling smoothly over time.
- **Dynamic Road Generation for Car Games:** The game continuously generates new road segments with randomized elements such as turns, hazards, and environmental features, offering players an endless and evolving driving challenge.

Optimization and Performance: Special care was taken to maintain smooth performance, even on limited hardware. Efficient use of sprite atlases, pooling techniques, and culling strategies helped minimize rendering overhead and memory consumption, ensuring a stable frame rate.
Future Scope:

- **Advanced Terrain Algorithms:** Implementing more sophisticated algorithms like Wave Function Collapse or Cellular Automata could enable more structured yet diverse terrain generation.
- **Biomes and Environmental Diversity:** Introducing different biomes (desert, forest, snow, etc.) with unique assets and mechanics can further enrich the player experience.
- **AI-Assisted Level Tuning:** Procedural generation could be enhanced with machine learning models that adapt level design in real-time based on player skill or behavior.
- **Multiplayer Integration:** Incorporating procedural content into online or co-op multiplayer games opens up possibilities for shared, unpredictable worlds that evolve with multiple players.
- **Cross-Genre Expansion:** The procedural generation system can be adapted to other game genres such as platformers, dungeon crawlers, or survival games, making it a reusable and scalable tool for future development.

Overall, this project lays a solid foundation for procedural content generation in 2D games, with numerous possibilities for refinement and expansion. Its modular design and performance-conscious implementation make it a strong

candidate for integration into full-scale game projects or future research.

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Secure Cloud Storage For Chatbot Logs And Conversation Data

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***Abstract*—In the era of intelligent conversational agents, chatbots are increasingly employed across diverse domains including healthcare, finance, education, and customer service. These chatbots generate large volumes of sensitive conversation data that must be securely stored to ensure confidentiality, integrity, and availability. This paper presents a robust cloud-based architecture for the secure storage of chatbot logs using Amazon Web Services (AWS). The system leverages AWS S3 for scalable storage, combined with AWS Key Management Service (KMS) and Advanced Encryption Standard (AES-256) to enforce strong encryption both at rest and in transit. Furthermore, the solution incorporates fine-grained access control, audit logging, and encryption key rotation to enhance security and compliance. Emphasis is placed on protecting user privacy, preventing unauthorized access, and ensuring the resilience of chatbot data against potential breaches or data loss. This work aims to provide a secure, reliable, and scalable storage framework that can be integrated with AI-driven conversational systems while meeting the demands of modern cybersecurity standards.**

I. Introduction

In today's digital era, chatbots play a crucial role in enhancing user interaction across various domains, including mental health support. However, the storage and security of chatbot conversation logs pose significant challenges, especially when handling sensitive user data. Ensuring the confidentiality, integrity, and availability of this data is essential to foster trust in such digital systems.

This paper presents the design and implementation of a secure, scalable cloud-based storage system specifically intended for storing chatbot conversation logs related to women's mental health. Considering the highly sensitive nature of these interactions, our solution incorporates robust encryption mechanisms, secure access controls, and compliance with data protection regulations.

The system leverages Amazon Web Services (AWS) technologies including S3 for cloud storage, Key Management Service (KMS) for key management, and employs AES-256 encryption for secure data storage. Additionally, Elliptic Curve Cryptography (ECC) is integrated to provide lightweight, secure authentication and integrity checks using digital signatures. These mechanisms collectively ensure that chatbot logs are protected against unauthorized access and tampering.

Beyond security, the system integrates efficient data management strategies such as optimized retrieval, indexing, and automated backups to ensure performance and scalability. By addressing critical privacy concerns and promoting ethical handling of sensitive user information, this project contributes to the development of trustworthy AI-powered mental health services.

II. Motivation

Chatbots that cater to women's mental health and safety frequently handle highly confidential personal data. Without proper protection, this information becomes vulnerable to

exploitation and misuse. Existing systems often lack the necessary security layers, making them inadequate for handling sensitive logs securely.

This work is driven by the need to develop a cloud storage solution that not only meets stringent security requirements but also ensures scalability and cost-effectiveness. By implementing AES-256 encryption, AWS KMS for key lifecycle management, and ECC for secure authentication, we aim to provide a holistic and robust approach to privacy-preserving chatbot systems.

III. Objectives

The core objectives of this work are:

- To design and develop a secure, cloud-based storage architecture for chatbot conversation logs using AWS services.
- To implement strong encryption and secure key management using AES-256 and AWS KMS.
- To incorporate Elliptic Curve Cryptography for authentication and integrity verification through digital signatures.
- To enable end-to-end encrypted communication between chatbot platforms and cloud storage.
- To optimize data retrieval, indexing, and backup mechanisms to support large-scale interactions without compromising performance.

These objectives aim to enhance the trust, security, and privacy of chatbot systems, especially in applications involving women's mental health and well-being.

- **User Interface (UI):** The Tkinter-based GUI allows users to input data, generate ECC signatures, and verify them interactively.
- **Cryptography Integration:** The demo utilizes the cryptography library for ECC key generation, signing, and verification.
- **Real-Time Execution:** The GUI provides an easy-to-use environment for visualizing ECC operations without requiring command-line interactions.

IV. Project Outline

The rest of the project report is organized as follows. In chapter 2, literature survey done for this project work is given. Chapter 3 presents the overall design of the proposed system. Chapter 4 describes the dataset used for the analysis. Chapter 5 deals with the experimental results associated with this project and Chapter 6 brings out the conclusion and future work.

V. Literature Survey

The security of chatbot conversation logs, particularly those involving sensitive top- ics like women's mental health, necessitates robust encryption and authentication techniques. Several studies have explored cryptographic methods to enhance cloud security, ensuring confidentiality, integrity, and availability of stored data. One significant study, "The Overview of Elliptic Curve Cryptography" by Yan, Y. (2021), discusses the advantages of Elliptic Curve Cryptography (ECC) in securing cloud-stored data. ECC offers strong encryption with smaller key sizes, making it more efficient than traditional cryptographic methods. This research highlights how ECC can be used in combination with AWS Key Management Service (KMS) to enhance key security and prevent unauthorized access to stored chatbot logs (Yan, 2021). Another relevant study, "Methods for Using Elliptic Curves in Cryptography" by Obukhov, V., Ivanova, E., Petrov, A. (2020), explores how ECC-based encryp- tion can secure chatbot logs while maintaining performance efficiency. The research emphasizes the importance of centralized key management using AWS KMS, which simplifies encryption and decryption operations while ensuring scalability and secu- rity (Obukhov, Ivanova, Petrov, 2020). For ensuring data integrity, "Security Improvement in Elliptic Curve Cryptogra- phy" by Abdullah, K. E., Ali, N. H. M. (2019), focuses on the Elliptic Curve Digital Signature Algorithm (ECDSA). The study explains how ECDSA can be used to au- thenticate chatbot logs, preventing unauthorized modifications. The integration of AES-256 for encryption and ECDSA for authentication provides a strong security model, ensuring that stored chatbot logs are both confidential and tamper-proof (Abdullah Ali, 2019). Additionally, the paper "Security Protocol Using ECC for Wireless Sensor Networks" by Qazi, R., Ahmed, M., Khan, S. (2018), highlights the benefits of ECC- based authentication for preventing unauthorized access to cloud-stored data. The study demonstrates how hash verification and bit-masking techniques can enhance data integrity, making it harder for attackers to modify chatbot logs undetected (Qazi, Ahmed, Khan, 2018). Finally, "Data Security in AWS S3 Cloud Storage" by Khande, R., Sharma, P., Verma, K. (2022), explores the effectiveness of combining AES-256 and ECC for enhanced cloud security. This study discusses the role of AWS KMS in managing encryption keys securely, reducing the risk of key exposure and unauthorized access. It also emphasizes the use of hybrid cryptographic approaches to optimize encryption performance without compromising security (Khande, Sharma, Verma, 2022). Overall, the literature review highlights the importance of strong encryption (AES, ECC), authentication (ECDSA), and secure key management (AWS KMS) in protecting chatbot logs. These techniques ensure that sensitive conversations remain confidential, secure, and protected from unauthorized access, making them ideal for cloud-based applications dealing with private user interactions.

VI. Literature Review

TABLE I
Literature Sources

SI No	Author	Title	Objective
1	Yuhan Yan	*The overview of elliptic curve cryptography*	Secure chatbot logs using ECC encryption, key management via AWS KMS, and integrity through ECDSA.
2	Vadim Obukhov et al.	*Methods for using elliptic curves in cryptography*	Enhance cloud security using ECC for chatbot logs, optimize AWS KMS, and ensure secure data protection.
3	Kawther Esaa Abdullah, Nada Hussein M.Ali	*Security improvement in elliptic curve cryptography*	Ensure confidentiality, integrity (ECDSA), and key management via AWS KMS with low computational load.
4	Rosheen Qazi et al.	*Security protocol using elliptic curve cryptography for wireless networks*	Use ECC-based ECDSA, masking, and hashing for integrity, confidentiality, and optimized performance.
5	Dr. Rajesh Khande et al.	*Data Security in AWS S3 Cloud Storage*	Enhance AWS S3 data security using encryption and access control.
6	S. Rizvi, A. Zoha, M. Khurshid	*Secure Chatbot Conversations in the Cloud using ECC-based Techniques*	Improve confidentiality and integrity of chatbot interactions by using ECC for data encryption and digital signatures.
7	H. Zhang, M. Liu, Y. Chen	*A Lightweight ECC Framework for IoT and Chatbots*	Propose a lightweight ECC-based security framework optimized for low-latency cloud-connected devices including chatbot.
8	Priya Sharma, Anil Kumar, R. Srivastava	*Hybrid Cryptographic Approach for Cloud Storage Security*	Combine ECC with AES to provide a hybrid encryption model that secures sensitive data in cloud storage.

VII. Background Study

The development of a secure cloud storage system for chatbot conversation logs is based on a comprehensive study of encryption techniques, cloud security frame- works, and chatbot data management. Ensuring data confidentiality, integrity, and availability is critical, particularly for chatbots handling sensitive user information, such as those focused on women's mental health.

A. Existing Challenges in Chatbot Data Security

Many chatbot systems store conversation logs without sufficient encryption or ac- cess controls, making them vulnerable to unauthorized access and potential data breaches. Given the sensitivity of mental health-related chatbot interactions, it is essential to implement robust security mechanisms to protect user privacy. Traditional encryption methods like AES-256 (Advanced Encryption Stan- dard) have been widely used for securing stored data. However, with increasing security demands, AWS Key Management Service (KMS) has emerged as a preferred solution for managing cryptographic keys securely. Additionally, Ellip- tic Curve Cryptography (ECC) has gained prominence in authentication and digital signatures due to its strong security properties with smaller key sizes.

B. Advancements in Secure Cloud Storage

Several research studies and industry implementations have explored different en- cryption strategies for cloud-based applications. Cloud service providers like AWS offer built-in encryption mechanisms such as server-side encryption (SSE) and client-side encryption, ensuring that data is secured before and after being up- loaded cloud. Secure access controls and authentication mechanisms are also neces- sary to prevent unauthorized users from accessing chatbot logs. Studies have also shown the effectiveness of combining encryption techniques with secure key management practices to enhance data security. AWS KMS provides a centralized approach to key generation, encryption, and decryption, re- ducing the risk of key exposure while maintaining compliance with security standards.

C. Relevance to the Project

By integrating AES-256 for encryption, AWS KMS for key management, and ECC for authentication, this project aims to provide a comprehensive security framework for chatbot logs stored in cloud environments. The imple- mentation of these techniques ensures that user conversations remain private and protected against potential cyber threats. This study forms the foundation for developing a highly secure and scal- able chatbot log storage system, ensuring data protection, compliance, and enhanced user trust. The project aligns with best practices in cloud security, making it a reliable and effective solution for safeguarding chatbot-generated data.

VIII. Proposed System

A. Problem Statement

Chatbots generate large volumes of conversation data, often containing sensitive user information. However, many existing storage solutions lack robust security measures, making them

vulnerable to unauthorized access, data breaches, and tampering.

This project aims to develop a secure cloud storage system for chatbot logs using AWS S3 encryption and AWS Key Management Service (KMS) with ECDSA digital signing. The solution ensures data confidentiality, integrity, and controlled access, protecting chatbot interactions from security threats.

B. System Architecture

The Secure Cloud Storage for Chatbot Logs and Conversation Data system is designed to ensure the confidentiality, integrity, and availability (CIA) of chatbot logs and sensitive user data. The architecture integrates AWS Key Management Service (KMS) for encryption and digital signing, enabling secure storage and retrieval through a structured workflow.

- **User Interface:** Enables interaction between users and the chatbot. Logs and conversation data are collected at this stage.
- **Encryption Layer:** Data is encrypted using AES-256 encryption with AWS KMS, ensuring strong data confidentiality.
- **Digital Signing:** To maintain data integrity, the data is digitally signed using Elliptic Curve Cryptography (ECC) keys managed by AWS KMS.
- **Cloud Storage:** The encrypted and signed data is securely stored in AWS S3, which is configured with fine-grained access controls and IAM policies.
- **Retrieval Mechanism:** On request, encrypted data is fetched from S3, decrypted using AES-256, and verified using the ECC digital signature to ensure integrity.
- **Access Control:** AWS IAM roles and policies enforce role-based access to ensure only authorized users can store and retrieve data.

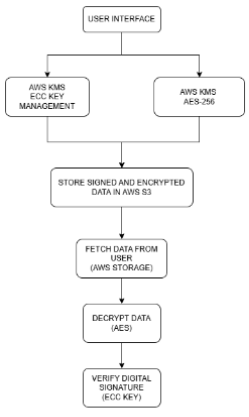

Figure 3.1: Data Flow Diagram

Fig. 1. Performance Comparison of AES, ECC, and AWS KMS Encryption

This architecture ensures a multi-layered security model that protects the stored chatbot logs from tampering and unauthorized access while maintaining performance and availability.

C. Technical Details

The proposed system integrates multiple AWS services and cryptographic techniques to ensure end-to-end security:

- **AES-256 Encryption:** Advanced Encryption Standard with a 256-bit key is used for encrypting chatbot conversation logs before storage. AES-256 offers robust data-at-rest protection.
- **Elliptic Curve Digital Signature Algorithm (ECDSA):** Used to sign each log entry digitally. This helps verify the authenticity and integrity of the data on retrieval. ECC provides strong encryption with smaller key sizes, reducing computational overhead.
- **AWS Key Management Service (KMS):** Manages all cryptographic keys used for both encryption and signing. AWS KMS securely generates, stores, and rotates keys, integrating seamlessly with S3 and Lambda.
- **Amazon S3:** Stores encrypted chatbot data. S3 provides high availability and durability. Bucket policies and IAM roles restrict access to ensure only authenticated and authorized users or services can access the data.
- **Identity and Access Management (IAM):** Role-based access control is enforced via IAM roles and permissions. Only users or services with appropriate roles can encrypt, decrypt, or access logs.
- **Decryption and Verification:** When data is retrieved, AES-256 is used to decrypt the content. The ECC digital signature is then verified to confirm data integrity.
- **Compliance and Audit Logging:** All encryption, decryption, and access events are logged using AWS CloudTrail for traceability and auditing purposes.

This secure architecture ensures confidentiality, integrity, and controlled availability of chatbot logs, while also adhering to privacy compliance standards such as GDPR and HIPAA.

IX. Methodology

The Secure Cloud Storage for Chatbot Logs and Conversation Data project follows a systematic approach to ensure data confidentiality, integrity, and availability. This methodology outlines the step-by-step process of data collection, encryption, signing, storage, and retrieval.

A. System Workflow

Data Collection

- The chatbot generates conversation logs and user interaction data.
- Logs are temporarily stored in memory before processing.

Data Signing (Integrity Verification)

- Each chatbot log entry is digitally signed using Elliptic Curve Digital Signature Algorithm (ECDSA).
- AWS KMS is used to generate ECC key pairs and sign the logs.
- The signature ensures that the data remains unaltered before encryption.

Data Encryption (Confidentiality Protection)

- Logs are encrypted using AES-256 with AWS KMS.

- Encryption ensures access is limited to authorized users.
- Signed and encrypted logs are prepared for storage.

Secure Storage in AWS S3

- Encrypted logs are stored in an Amazon S3 bucket.
- IAM roles and bucket policies restrict access.
- S3 versioning maintains log versions.

Data Retrieval and Verification

- Encrypted logs are retrieved on request.
- Logs are decrypted using AES-256.
- ECC signature is verified using AWS KMS.

B. Security Measures and Access Control

- AES-256 encryption ensures data confidentiality.
- ECDSA signing guarantees data integrity.
- IAM policies and access control prevent unauthorized access.
- AWS KMS secures encryption and signing keys.

X. Dataset

The dataset comprises real-time chatbot interactions and user authentication data. The system dynamically records conversation logs and user data, ensuring that all stored information is encrypted and digitally signed before being stored in AWS S3.

- Chatbot logs include queries, responses, and timestamps, stored in structured JSON format.
- Test cases include general queries, personalized responses, and concurrent user sessions to evaluate stability.

XI. Experimental Results

A. AES vs AWS KMS Encryption Experiment

1) AES-256 Encryption Implementation: AES-256 is a symmetric algorithm used to encrypt chatbot logs, ensuring confidentiality and integrity. The process involves:

- Key generation
- Log encryption
- Secure cloud storage

2) AWS KMS Encryption Implementation: AWS Key Management Service (KMS) provides secure encryption key handling. KMS was used for encrypting chatbot logs, offering:

- Key generation and access control
- Seamless integration with AWS S3

TABLE II
Comparison of AES-256 and AWS KMS Encryption

Criteria	AES-256	AWS KMS
Encryption Type	Symmetric	Asymmetric/Symmetric
Key Management	User-Managed	AWS-Managed
Security	Strong	Enhanced with Access Control
Performance	Fast	Slightly Slower (API calls)
Integration	Manual Setup	Seamless AWS Integration

3) Comparison of AES and AWS KMS Encryption:

4) Summary: Both AES-256 and AWS KMS are secure. AES-256 offers faster performance, while AWS KMS provides better key management and AWS integration.

Fig. 2. Performance Comparison of AES, ECC, and AWS KMS Encryption

B. AES vs ECC Encryption Experiment

1) AES-256 Encryption: Symmetric, fast, secure encryption used for encrypting chatbot logs.

2) ECC Encryption: ECC is an asymmetric algorithm offering high security with small key sizes. It uses:

- Private-public key pair
- Encryption using public key
- Decryption using private key

TABLE III
Comparison of AES-256 and ECC Encryption

Criteria	AES-256	ECC
Encryption Type	Symmetric	Asymmetric
Key Size	256-bit	256-bit
Security	Strong	Stronger per bit
Performance	Fast	Slower
Key Management	Requires key sharing	No key sharing
Computational Overhead	Low	High

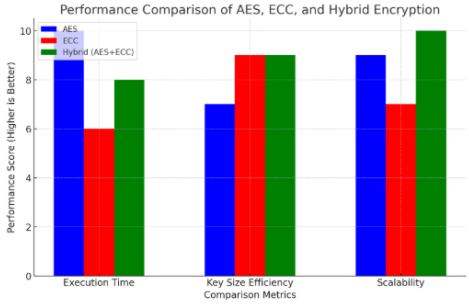

Fig. 3. Performance Comparison of AES, ECC, and Hybrid Encryption

3) Comparison of AES and ECC Encryption:

4) Summary: AES-256 is efficient and fast for large data encryption. ECC is optimal for secure communication and signature validation, though it involves more computation.

C. Demonstration and Screenshots

This section presents the demonstration of the encryption implementation along with relevant screenshots.

Elliptic Curve Cryptography (ECC) is an efficient public-key cryptographic technique that offers strong security with

smaller key sizes. This demo showcases ECC encryption and decryption using a Tkinter-based GUI.

1) The user inputs a message.
2) A key pair is generated.
3) The message is encrypted and displayed.
4) The system checks if the message is tampered or not.

The demonstration successfully highlights ECC's efficiency in encryption and decryption, showcasing its advantages over traditional algorithms like RSA. The GUI makes cryptographic operations more accessible and user-friendly.

Future improvements could include integrating digital signatures for authenticity verification and adding performance benchmarking to evaluate encryption and decryption speed under different scenarios.

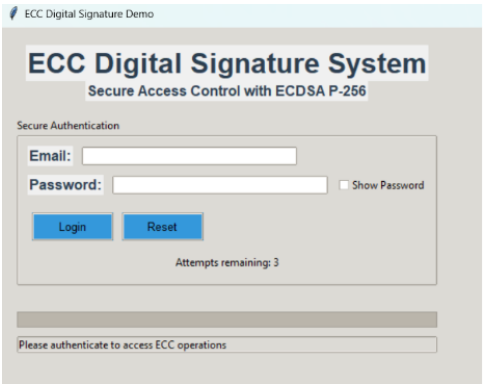

Fig. 4. Login Authentication Interface

If the right email and password, only then will the rest of the ECC operations be visible. A user can try entering into the system 3 times.If all those attempts are wrong then, The system gets locked.

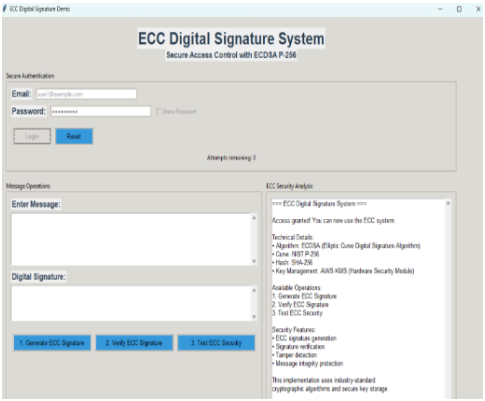

Fig. 5. Message Signing and Verification

After the message is entered, the digital signature will be generated by clicking the 'Generate ECC Signature' button.

Tests confirmed key pair uniqueness, encryption-decryption accuracy, and data integrity using cryptographic hashing. AWS KMS integration ensures secure key storage. ECC provides strong encryption with smaller key sizes, resisting brute-force attacks and enhancing data confidentiality. Audit logging tracks encryption and decryption activities.

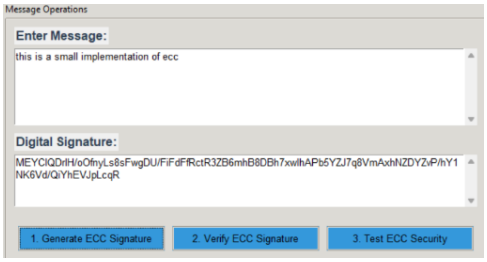

Fig. 6. Generating ECC Signature

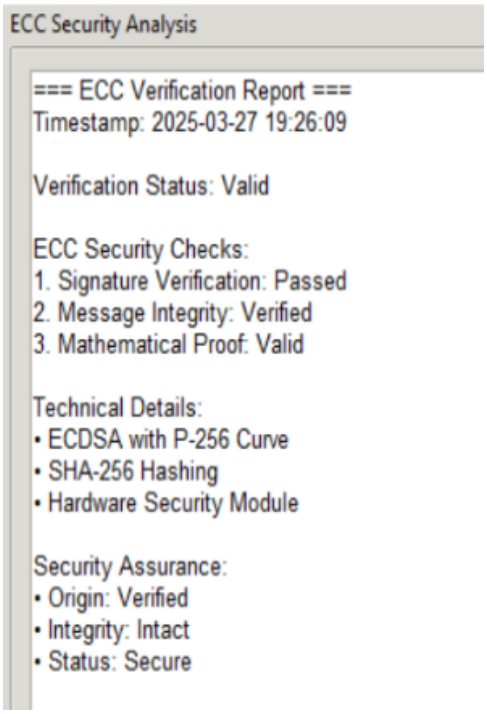

Fig. 7. Verification Report and Security Analysis

Fig.7 shows the screenshot of the original message being entered. Fig 5.10 shows the screenshot of the message being tampered by adding a new sentence to the original messsage.

Fig. 8. ECC Digital Signature Verification

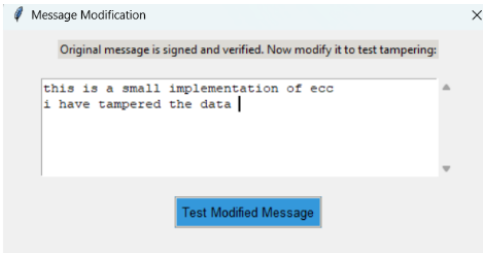

Fig. 9. ECC Data Tampering Process

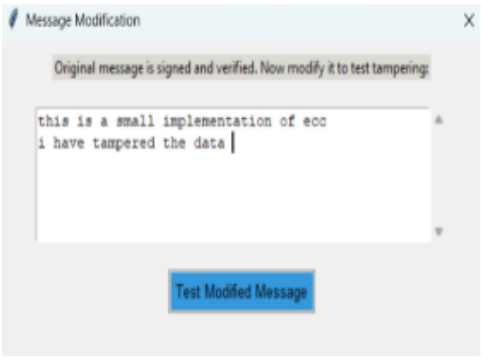

Fig. 10. Tampering Detection Window

After the message is tampered with, a security alert window appears that shows that the message is being tampered with.

XII. Acknowledgment

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Conclusion and Future Scope

This project aimed to design and implement a highly secure cloud storage system for chatbot logs, focusing on safeguarding sensitive information, particularly related to women's mental health. By leveraging advanced encryption techniques such as AES-256, AWS Key Management Service (KMS), and Elliptic Curve Cryptography (ECC), the system ensures the confidentiality, integrity, and availability of stored data. The integration of secure access controls and authentication mechanisms further enhances the security of the logs, ensuring that only authorized users can access the sensitive data.

The cloud-based storage solution ensures scalability and efficient management, while data retrieval, backup, and indexing mechanisms optimize system performance. This system has been designed with compliance to privacy regulations in mind, ensuring responsible data handling in line with best practices.

Looking ahead, the secure cloud storage system could be enhanced by incorporating machine learning algorithms to detect abnormal access patterns or unauthorized access attempts in real-time, improving threat detection capabilities. Additionally, further improvements can be made by exploring multi-cloud solutions, which would allow for even greater data redundancy and reliability across multiple platforms.

The system could also be expanded to handle more diverse forms of sensitive data, such as audio and video logs, further enhancing its applicability in healthcare and mental health domains. Moreover, integrating automated backup solutions and improving system scalability would make the system better suited for large-scale deployments, ensuring its effectiveness in real-world applications. Finally, further research could focus on streamlining the encryption and decryption processes to minimize performance overhead, especially as data volume increases.

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Fake Currency Authenticity Through Imaging

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***Abstract*—Fake currency circulation poses a significant threat to economies worldwide. To address this issue, our project focuses on fake currency detection using image pro-cossing, leveraging the power of Python for implementation. The system analyzes currency images using advanced computer vision techniques and machine learning algorithms to identify counterfeit notes with high accuracy. A key enhancement of our project is the introduction of a dynamic update feature, allowing users to add and verify new currencies. This ensures that the system remains adaptable to evolving counterfeiting techniques and new currency designs. The detection process involves feature extraction, pattern recognition, and classification techniques, mak-ing it a robust and scalable solution for real-world applications. Our proposed system. aims to assist financial institutions, businesses, and individuals in effectively identi fying counterfeit notes, reducing financial risks, and enhancing transaction security..**

***Index Terms*—Currency authentication, Image processing, Edge detection, Feature extraction, Fake note detection.**

I. Introduction

In today's digital era, counterfeit currency remains a persistent threat to economic stability and financial security. The rise of sophisticated printing tech-nologies has made it increasingly challenging to differentiate between genuine and fake notes using conventional methods. To address this issue, our project, Fake Currency Authenticity Analysis Using Image Processing, presents an advanced so-lution that leverages computer vision and machine learning techniques for reliable and automated detection of counterfeit currency.

System is implemented using Python, utilizing its extensive libraries such as OpenCV, TensorFlow, and NumPy to analyze currency images based on various distinguishing features, including texture, color patterns, and security markings. Through feature extraction and classification algorithms, the system determines the authenticity of a given note with high precision. A key innovation in our project is the dynamic update feature, which allows users to add and verify new currency types. This ensures that the system remains adaptable to the introduction of new denominations and evolving counterfeiting techniques. By integrating this feature, our solution provides a scalable and future-proof approach to currency authentication.

The proposed system is designed to assist banks, financial institutions, busi-nesses, and individuals in minimizing financial losses due to counterfeit money. With its ability to analyze and validate currency authenticity efficiently, this project contributes to enhancing transaction security and reinforcing trust in financial ex-changes.

II. Literature Survey

Detection of Fake Currency using Image Processing (2020) Published in the Inter-national Journal of Engineering Research Technology (LJERT), this study explores the use of image processing techniques to detect counterfeit currency. The primary function of this approach is to extract distinguishing features from currency notes, such as edges, textures, and unique patterns. Methods like edge detection and tex- ture analysis are employed to differentiate genuine and fake notes. The integration of machine learning algorithms for classification enhances accuracy, making the sys-tem practical for real-world applications. The benefit of this approach lies in its ro-bust feature extraction, which significantly reduces false positives. [2 Fake Currency Detection using Image Processing (2021) In the 2021 International Conference on Advancements in Electrical, Electronics, Communication. Computing and Automa tion (ICAECA), Latha et al. present a comprehen- sive approach involving pattern recognition and digital image processing. The functions include histogram analy-sis, pattern matching, and key feature comparison. The system's benefit is its high detection accuracy, even in varying lighting conditions, making it reliable for prac-tical deployment. The use of real-world datasets adds credibility to its robustness. and efficiency.

[3] Fake Currency Detection using Image IOP (2017) This

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paper, pub-lished in the IOP Conference Series: Materials Science and Engineering, discusses a novel methodology that combines image segmentation and texture pattern analysis. The primary function of this approach is to detect minute discrepancies between gemuine and counterfeit notes through texture pattern recognition. The benefit of this method is its precision in identifying subtle variations that are often overlooked by traditional techniques. It addresses practical challenges, including variations in currency conditions and wear.
[4] Detection of Fake Currency using Image Process- ing (2024) Published in the International Research Journal of Modernization in Engi-neering, Technology, and Science (IRIMETS), this study introduces a convolutional neural net-work (CNN) architecture for fake currency detection. The function of CNN in this context is to automatically learn hierarchical features from input im-ages, enhancing detection accuracy. The benefit of using deep learning lies in its ability to generalize across diverse currency types and conditions. The study demon-strates that CNNs outperform traditional methods in precision and speed. [5] Fake Currency Detection in Image Processing using MATLAB (2022) This study, pub-lished in the International Journal of Research Publication and Reviews (IJRPR), employs MATLAB for image processing in fake currency detection. Functions in-clude color extraction, feature matching, and template comparison. The system isparticularly beneficial for its case of implementation and adaptability to different currencies. The use of MATLAB's robust libraries allows for efficient computation and visualization of results.
[6] Detection of Fake Currency using Image Processing (2020) Another study published in LJERT discusses the integration of digital image processing with feature extraction methods. The primary function is to enhance the accuracy of counterfeit detection through advanced image preprocessing tech-niques. Benefits include robustness against varying lighting conditions and practical usability for automated systems. [7] Fake Ban-knote Recognition using Deep Learn-ing (2021) Published in Applied Sciences, this study by Pacho´n et al. leverages deep learning for counterfeit banknote recognition. The CNN- based system's function is to identify fake notes from diverse datasets accurately. The benefit of this approach is its ability to achieve high precision with minimal human intervention, making it suitable for real-time applications. [8] ANN-based Fake Currency Detection System (2020) In the International Journal of Computer Graphics (LJCG), Sambana and Mahanty propose an artificial neural networks (ANN)-based detection system. The function of ANN is to learn complex patterns and correlations between genuine and counterfeit notes. Its computational efficiency and high detection accuracy make it a promising solution for automated systems.

III. Existing System

The current systems of currency verification are primarily rely on physical devices such as UV sensors and water- mark checkers. While effective, these methods require human are regulated and governed by human beings. They also do does not allow automatic batch processing of multiple notes.

IV. Proposed System

3.1 PROBLEM STATEMENT

Counterfeit currency poses a significant challenge to economies worldwide, leading to financial losses and undermining trust in financial institutions. Traditional methods of counterfeit detection, such as manual inspection and ultraviolet scanning, are often time-consuming, error-prone, and require specialized equipment. With advancements in artificial intelligence and deep learning, automated image-based detection systems offer a promising solution to enhance the accuracy and efficiency of counterfeit currency identification.

3.2 PROPOSED SYSTEM OUTLINE

The Fake Currency Detection System using Image Processing leverages deep learning techniques to classify banknotes as real or fake. Users upload an image of the currency, which undergoes preprocessing, including resizing, normalization, and data augmentation. A Convolutional Neural Network (CNN), specifically Mo-bileNet V2, extracts key features from the image using transfer learning. These features are then passed through fully connected layers for binary classification, de-termining whether the currency is genuine or counterfeit. The system outputs the prediction along with a confidence score, providing an efficient and automated solu-tion for counterfeit detection.

3.3 SYSTEM ARCHITECTURE

EXPLANATION:The Fake Currency Detection System us-ing Image Processing is designed to classify banknotes as real or fake using deep learning techniques. The system begins with user interaction, where users upload images of the currency for analysis. The preprocessing module loads the image using the PIL library, resizes it to a standard 224x224 resolution, normalizes pixel values, and applies data augmen-tation techniques such as rotation, zoom, and shifting to enhance model robustness. The feature extraction module employs a MobileNet V2 convolutional neural net- work (CNN), which is pretrained on the ImageNet dataset. Transfer learning and fine-tuning are used to extract essential features from the currency images. These extracted features are then passed to the classification module, consisting of fully connected layers and a binary classification system that uses a sigmoid activation function to determine authenticity. The decision and output module generates a con-fidence score and classifies the currency as "Real" or "Fake." The system is trained on an image dataset stored in Google Drive, and it utilizes TensorFlow's Image-DataGenerator for real-time data augmentation and loading. To improve model performance, class weights are adjusted, and early stopping is implemented

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to pre-vent overfitting. After training, the model is evaluated on a test set, and the final model is saved for future predictions. The system also includes a function for pro-cessing individual images, enabling real-time fake currency detection with a prede-fined confidence threshold. The architecture ensures efficient classification with high accuracy, making it a practical tool for counterfeit detection.

for such attributes using techniques like:

- Grayscale Conversion
- Histogram Equalization
- Canny Edge Detection
- Feature Matching

3.4 TECHNICAL DETAILS

The project focuses on detecting counterfeit currency using image processing and deep learning techniques. It leverages the power of transfer learning with the MobileNet V2 model, a well-known convolutional neural network architecture pre- trained on the ImageNet dataset. The goal is to accurately classify images of currency as either fake or real using a robust, efficient model. The implementation is done using TensorFlow and Keras libraries and is designed to work efficiently within the Google Colab environment.

The first step involves setting up the environment by mount-ing Google Drive, which allows seamless access to dataset and model storage. The data is organized into three main folders: train, validation, and test, each containing subdirectories for fake and real currency images. To ensure data consistency and organization, the code dynamically creates directories if they do not already exist. The images are then loaded from the training folder, and the data is split into training and validation sets using an 85-15

Data augmentation plays a crucial role in enhancing model performance and generalization. Techniques such as rotation, width and height shifting, shearing, zooming, and rescaling are applied to make the model resilient to variations in input images. Image normalization is performed by scaling pixel values to the range of 0 to 1. These transformations not only improve accuracy but also help the model become robust to real-world variations. The augmented images are then loaded into data generators, which feed the data in batches during model training.

The model architecture utilizes MobileNet V2 as the base model, which is pre-trained on the ImageNet dataset. The initial layers of the model are frozen to retain the learned features, while the top layers are customized for the fake currency detection task. This transfer learning approach allows the model to leverage existing knowledge and adapt it to the specific problem. Custom classification layers are added on top of the base model, including a global average pooling layer, a dense layer with ReLU activation, a dropout layer to reduce overfitting, and a final output layer with a sigmoid activation function for binary classification. The model is compiled using the Adam optimizer and binary crossentropy loss function, suitable for binary classification tasks.

Training the model involves defining early stopping to avoid overfitting and using class weighting to balance the classes since the dataset may have imbalanced samples of fake and real currencies. The model is trained for up to 20 epochs with monitoring on validation loss to decide when to stop training. After training, the model's performance is evaluated on both training and testing datasets to ensure its accuracy and generalization. The model is also saved to disk for future inference.

For real-time prediction, the system includes functions to preprocess a single image and predict its authenticity. The input image is resized, normalized, and passed through the trained model to obtain a confidence score. A threshold value determines whether the currency is classified as real or fake. Additionally, utility functions are provided for managing datasets, uploading new images, and triggering model training when needed.

Overall, the project demonstrates a comprehensive approach to counterfeit cur-rency detection by combining convolutional neural networks with image processing techniques. It effi- ciently handles data augmentation, model training, and real- time prediction while ensuring robust performance through transfer learning and careful model optimization. A positive match across all features results in authentication of the note.

V. DATASET

The dataset used in this code is a collection of currency images specifically. prepared for detecting fake and real cur-rency notes. It is stored in Google Drive and organized into separate folders and subfolders to facilitate training, validation, and testing. The main directory, named "Currency dataset," contains three primary subdirectories: "train," "validation," and "test." Each of these subdirectories is further divided into two subfolders, "fake" and "real," which contain images of fake and real currency notes, respectively. The training folder holds the largest portion of the dataset and is used to train the neural network to distinguish between real and fake currency notes. The validation folder contains images used to evaluate the model's performance during training and is usually set to be 15 percent of the training data, as specified in the code. The test folder, which also has separate subfolders for fake and real currency images, is used to assess the final performance of the trained model, providing an unbiased evaluation.

To enhance the robustness of the model, data augmentation techniques are em-ployed using TensorFlow's ImageDataGen- erator. These techniques include rescaling pixel values to the range [0, 1], rotating images randomly by up to 15 degrees, shift-ing the images horizontally and vertically by 10 percent, applying shear and zoom transformations, and filling miss- ing pixels using the nearest pixel value. Horizontal flipping is deliberately disabled to maintain the fixed orientation of currency notes. All images are resized to 224x224 pixels to match the input shape expected by the MobileNet V2 model, and they are normalized to float values between 0 and 1 by dividing pixel values by 255. Images are loaded using the PIL library and

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converted into numpy arrays before being passed

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Figure 5.2: user login page

Fig. 1. Log in page

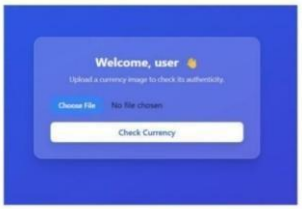

Figure 5.3: choosing file

Fig. 2. Choose file

to the model. In summary, the dataset consists of fake and real currency images gathered from various sources, organized sys- tematically to ensure effective model training, validation, and testing. Data aug-mentation is utilized to artificially increase the dataset size and improve the model's ability to generalize to unseen images.

VI. Implementation

Implementation is done by employing MATLAB. The soft-ware processes the captured image and extracts regions of interest. The algorithm follows these steps:

1) Image acquisition using a high-resolution camera.
2) Preprocessing to reduce noise and enhance image qual-ity.
3) Segmentation to isolate key features.
4) Feature extraction and matching with templates of gen-uine notes.

The GUI developed in MATLAB allows users to upload currency images and displays results after processing.

VII. Experimental Results

Testing was carried out in Indiancurrency using thenotes of respective denominations. Dealt with real and fake bills The system was efficient in terms of forgeries when they were accompanied only with frictional properties, unlike the characteristics that must be present watermark and thread. The API response time to predict was less than 3 seconds per note, making it applicable for on-line use. VII. Conclusion The described system serves as an example of how image processing techniques can be used for authentication purposes, especially on Indian currency notes. Although other developments like machine learning might improve robustness, this model is suitable for easy and fast verification.

5.1 User Login

The figure shown below represents the login page of the Fake Currency De tection System, designed using modern UI elements to provide a smooth and user-friendly experience. The login page ensures secure access by requiring a valid user-name and password combination. Upon successful authentication, users are granted access to the dashboard,

Fig. 3. Authenticity analysis

where they can utilize the system's image processing capa-bilities to detect counterfeit currency. This page serves as the gateway to the core functionalities of the system, which leverages advanced image processing techniques to analyze currency images and verify their authenticity. The implementation of secure login mechanisms helps maintain the integrity of user data and system performance.

5.1.1 Choose file

Upon successful login, users are greeted with the Fake Currency Detection System, where they can initiate the currency verification process by uploading an image of the currency note. The interface is designed to be intuitive and user-friendly, allowing users to easily select a file using the "Choose File" button. Once an image is uploaded, users can click the "Check Currency" button to trigger the detection algorithm. The system then processes the uploaded image to determine the authenticity of the currency. The detection results are displayed on the dash-board, providing users with accurate and prompt feedback. This streamlined process ensures that users can quickly and efficiently verify currency authenticity using ad-vanced image processing techniques.

5.1.2 Checks the authenticity.

The below image depicts a user interface for a fake currency detection system utilizing image processing. Users can upload an image of a currency note, which the system analyzes to determine its authenticity. The interface displays

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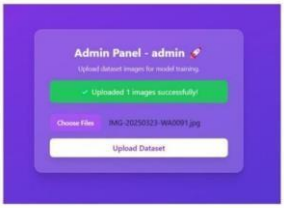

Figure 5.6: upload dataset

Fig. 4. Admin panel

the uploaded file and provides a ”Check Currency” button to initiate the analysis. Upon process-ing, the system returns a result indicating whether the currency is ”Real Currency” or ”Fake Currency”, along with a confidence percentage, in this case, 89.32per-cent. Additionally, the system highlights specific security features detected, such as ”Security thread”, ”Watermark”, and ”Microprinting”, which contribute to the suthenticity assessment. This process allows users to quickly and efficiently verify the legitimacy of currency notes through image analysis, enhancing security and reducing the risk of counterfeit transactions.

5.2 Admin Login

The admin interface, as depicted in the image, provides a crucial function for the fake currency detection system, dataset management, for model training. Admins can utilize this panel to upload images of currency notes, both genuine and counterfeit, to build a comprehensive data set. The interface features a simple ”Choose Files” button to select multiple images and an ”Upload Dataset” button to initiate the transfer. This uploaded data set is then used to train the image processing model, enabling it to accurately discern between real and fake currency based on the visual features extracted from the images. By facilitating efficient dataset uploads, this admin panel plays a vital role in ensuring the system’s accuracy and reliability in detecting counterfeit currency, thus strengthening the overall security of the application.

5.2.1 Upload of data set

The image illustrates a key step in the development of a fake currency de tection system: dataset upload for model training. The admin panel, designed for this purpose, confirms the successful upload of image indicating that the system. is ready to incorporate this image into its training dataset. By allowing adminis trators to efficiently upload images of both gemine and counterfeit currency, the system ensures the model is trained on a diverse and representative dataset. This process is crucial for enhancing the accuracy and robustness of the image processing algorithm, enabling it to effectively identify subtle differences between real and fake currency notes. The successful upload, as indicated by the green confirmation mes sage, marks a vital stage in building a reliable and effective fake currency detection tool.

VIII. Conclusion

particularly beneficial for its case of implementation and adaptability to different currencies. The use of MATLAB’s robust libraries allows for efficient computation and visualization of results. [6] Detection of Fake Currency using Image Processing (2020) Another study published in LJERT discusses the integration of digital image processing with feature extraction methods. The primary function is to enhance the accuracy of counterfeit detection through advanced image preprocessing tech-niques. Benefits include robustness against varying lighting conditions and practical usability for automated systems. [7] Fake Banknote Recognition using Deep Learn-ing (2021) Published in Applied Sciences, this study by Pacho´n et al. leverages deep learning for counterfeit banknote recognition. The CNN-based system’s function is to identify fake notes from diverse datasets accurately. The benefit of this approach is its ability to achieve high precision with minimal human intervention, making it suitable for real- time applications. [8] ANN-based Fake Currency Detection System (2020) In the International Journal of Computer Graphics (LJCG), Sambana and Mahanty propose an artificial neural networks (ANN)-based detection system. The function of ANN is to learn complex patterns and correlations between genuine and counterfeit notes. Its computational efficiency and high detection accuracy make it a promising solution for automated systems.

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SLOT BOOKING APPLICTION: SpotON

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***Abstract*—The Slot Booking App is a user-friendly platform that allows customers to book time slots for services like hotel rooms, restaurant reservations, spa treatments, and event spaces. It offers real-time availability checks, secure payment options, and booking management features, including cancellations and rescheduling. The app also provides an admin dashboard for managing reservations and availability. This solution streamlines the booking process, reducing conflicts and enhancing convenience for both users and service providers**

***Index Terms*—Slot Booking System, Online Scheduling, Mobile Application,Reservation System, Real-Time Systems, User Interface Design, Web-Based Services, Data Management**

I. INTRODUCTION

Motivation

In most service-oriented establishments like barbershops, saloons, clinics, and repair shops, unorganized walk-ins and lengthy waiting periods result in unhappy customers and wasting both the clients' and service providers' time. As there is a growing demand for hassle-free and contactless services, there is a need for a system that streamlines the process of making appointments while enhancing the management of time and flow of customers. The impetus for SPOT ON is to eliminate the world of book disorder and never-ending queues through an online space where clients can make time bookings at their convenience. By automating time booking, the app facilitates streamlined business operations and offers the clients more control over their schedules. This provides a cleaner, professional, and user-friendly experience in service, especially in high-demand environments like barbershops.

Scope and Challenges

Multi-Platform Accessibility: Designed to operate across mobile and web platforms, allowing users to book slots anytime and anywhere.

Dynamic Slot Management: Real-time tracking and allocation of available slots based on time, location, service provider, or resource.

Concurrency Handling: Managing multiple users trying to book the same slot simultaneously requires efficient real-time syncing and conflict resolution mechanisms.

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Our Contribution

The proposed slot booking application contributes signifi- cantly to the field of online scheduling systems by addressing several practical, technical, and user-centric concerns. The major contributions of this work include:

- Implemented using modern mobile and web technologies (e.g., React Native / Node.js / HTML / css), the system allows seamless booking, management.
- integrated email or push notification systems to alert users about their bookings, cancellations, and upcoming appointments, improving engagement and reducing no- shows.
- The architecture is adaptable for different use cases like hospital appointments, academic lab slot booking, park- ing reservations, or salon bookings, making it versatile.

The slot booking application is built using a client-server model where the frontend (React Native/HTML/CSS), Users can log in, view available slots, and book them in real-time. The system ensures no double bookings through atomic op- erations and provides role-based access for users and admins. Notifications are sent upon booking or cancellation, and the design supports scalability and integration with future features like payments or AI-based suggestions.

II. Literature Survey

Slot booking and scheduling systems have gained significant attention in recent years due to their applicability across various domains such as healthcare, education, parking, and service-based businesses. Several studies have focused on enhancing the efficiency, scalability, and user experience of such systems.

R. Sharma and A. Verma [**?**], Developed a web-based system to simplify doctor appointment bookings by allowing patients to register, view doctor availability, and book slots online. Built using PHP and MySQL, it includes user, doctor, and admin modules. The system reduces manual scheduling and clinic wait times but lacks real-time updates and mobile support, highlighting areas for future enhancement.

D. Thomas and K.Joseph [**?**] is another notable system, designed specifically for mental health support using scripted

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responses and decision-tree logic. While scalable, it lacks neural generalization and is rigid in terms of intent interpretation.

S.Patel and M.Kaur [**?**] S. Patel and M.Kaur proposed a real-time appointment scheduling system using Firebase as the backend. The system offers user authentication, real-time slot updates, and push notifications. It provides a scalable and responsive interface, ensuring conflict-free bookings. However, the system focuses primarily on core functionality and lacks advanced features like analytics and role-based dashboards, which can be added in future improvements.

A.Kumar and P.Singh [**?**] A.Kumar and P.Singh introduced a smart parking system integrating IoT sensors with an online slot booking platform. The system detects real-time parking slot availability using sensors and allows users to reserve slots through a web or mobile interface. It improves parking efficiency, reduces congestion, and minimizes wait time. However, the model assumes consistent sensor connectivity and does not address scalability challenges in large urban environments.

Our work differs by implementing a lightweight, modular slot booking system using modern web and mobile technologies, focusing on real-time functionality and scalability. By leveraging a simple yet effective architecture comprising a React-based frontend and a Firebase-powered backend—we demonstrate that reliable scheduling can be achieved without the overhead of complex infrastructure. This system serves as a practical proof-of-concept for building accessible, low-maintenance slot booking solutions suited for educational, healthcare, and public service contexts, while remaining extensible for future enhancements like analytics and payment integration.

III. Background Concepts

This section outlines the foundational concepts necessary to understand and develop a slot booking application. The discussion spans the system architecture, backend processing, data storage, and mechanisms ensuring reliability and real-time performance.

A. Web-Based Application Architecture

Slot booking systems are typically web-based applications that follow a **client-server architecture**. The client-side (frontend) is responsible for interacting with users, while the server-side (backend) handles business logic, authentication, and database transactions. Key features of this architecture include:

- **Frontend:** Built using HTML, CSS, and JavaScript frameworks such as React or Angular to provide a dynamic and responsive user interface.
- **Backend:** Implemented using server-side technologies like Node.js, Flask, or Django to handle API requests, logic execution, and database interactions.
- **Communication:** The client communicates with the server through HTTP requests or RESTful APIs, sending

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data such as slot selections, user credentials, and booking confirmations.

B. Database Management

Central to the slot booking system is the use of a structured database to manage resources, users, and time slots. Both **Relational Databases** (like MySQL, PostgreSQL) and **NoSQL Databases** (like MongoDB, Firebase) are commonly used depending on the use case. Critical elements stored in the database include:

- **Users:** Information about registered users, including au- thentication details and booking history.
- **Slots:** Time slots with associated metadata such as dura- tion, capacity, and availability status.
- **Bookings:** Records that link users with specific slots, often with timestamps and status flags.

Efficient database indexing and ACID-compliant transactions help ensure reliable performance under load.

C. Concurrency and Overbooking Prevention

One major challenge in slot booking systems is preventing **overbooking** when multiple users attempt to reserve the same slot simultaneously. To address this, mechanisms such as:

- **Atomic Transactions:** Ensuring a booking is only con- firmed if the slot is available at the moment of database write.
- **Locking Mechanisms:** Using pessimistic or optimistic locks to block conflicting transactions during booking operations.
- **Availability Checks:** Real-time validation of slot status before confirming any reservation.

These strategies preserve data integrity and provide a consistent user experience.

D. Real-Time Slot Status and User Feedback

To enhance interactivity and reduce booking conflicts, many systems provide **real-time updates** of slot availability. This is achieved using:

- **WebSockets or Server-Sent Events (SSE):** For pushing updates to clients when a slot's availability changes.
- **AJAX Polling:** Periodically checking the server for up- dated data without reloading the page.
- **Push Notifications:** Alerting users when new slots be- come available or if their session is about to expire.

Real-time interaction minimizes booking errors and improves system responsiveness.

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E. Authentication and Access Control

Ensuring that only authorized users can book or manage slots is critical. This is handled by:

- **Authentication:** Users log in using credentials; methods include traditional email/password systems or OAuth-based social logins.
- **Authorization:** Role-based access control (RBAC) ensures only admins can add or remove slots, while regular users can only book them.
- **Session Management:** Maintaining secure user sessions with token-based systems like JWT (JSON Web Tokens).

F. User Experience and Interface Design

A streamlined, intuitive interface is key to user satisfaction. Features include:

- **Calendar Integration:** Visual calendars or timeline views to select slots intuitively.
- **Filtering and Search:** Options to find available slots based on date, location, or category.
- **Confirmation and History:** Immediate booking confirmation and access to past bookings.

Our slot booking application prioritizes simplicity and mobile responsiveness to cater to a wide range of users and devices.

IV. PROPOSED SYSTEM: SLOT BOOKING APPLICATION

In this section, we detail the architecture and implementation of our lightweight slot booking application. Designed with simplicity, responsiveness, and accessibility in mind, the system allows users to register, view available slots, and make reservations via a clean and user-friendly interface. The backend ensures real-time updates and prevents overbooking through efficient data handling.

A. Dataset and Slot Representation

The system manages data representing users, services, and time-bound slots. Each slot is associated with metadata such as time, date, location (if applicable), capacity, and status (available/booked). To model this effectively, we define:

- **User Records:** Contain basic credentials and user history.
- **Slot Records:** Define time intervals, availability status, and limits (e.g., number of users per slot).
- **Booking Records:** Map users to specific slots, including timestamps and booking confirmation.

The data is stored in a structured database (e.g., MySQL or Firebase), and indexed for fast retrieval.

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B. System Architecture

Our slot booking system uses a modular client-server archi- tecture that separates concerns across the frontend, backend, and database layers. The workflow proceeds as follows:

User Interface (Frontend) → API Requests (Backend) → Slot Validation & Storage (Database)

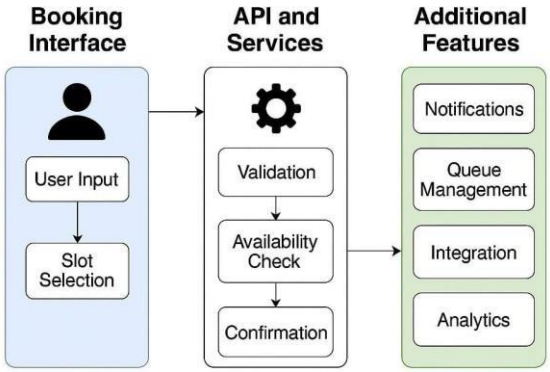

Fig. 1. Architecture of the Slot Booking Application

- **Frontend:** Implemented using React, it displays slots us- ing calendar views and provides feedback on availability.
- **Backend:** Built using Node.js or Django, this layer handles API logic, booking validations, and real-time updates.
- **Database:** A real-time database like Firebase or a rela- tional schema using MySQL stores user, slot, and booking data.

C. Booking Mechanism

The core feature of the application is the ability to reserve available slots. The process includes the following steps:

- **Slot Retrieval:** The frontend fetches available slots through a RESTful API call.
- **Selection and Submission:** The user selects a slot and submits a booking request.
- **Validation:** The backend verifies the slot's availability in real-time to avoid concurrency conflicts.
- **Confirmation:** If available, the booking is stored in the database and the slot is marked as reserved.

Concurrency control ensures that two users cannot book the same slot simultaneously, utilizing atomic operations or Fire- base transactions.

D. Real-Time Feedback and Updates

To enhance user experience and ensure accuracy in slot visibility, the system incorporates:

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- **WebSockets (or Firebase listeners):** For live updates on slot status without page reloads.
- **Loading Indicators and Notifications:** Inform users about booking status or errors (e.g., slot already taken).
- **Calendar Synchronization:** Slots can be linked to personal calendars via export or integration (optional).

E. Deployment and Scalability

The system is deployable on cloud platforms such as Firebase, Heroku, or AWS, ensuring scalability and uptime. Features include:

- **Authentication:** Google OAuth or email/password login via Firebase Auth.
- **Hosting:** Static frontend files deployed via Firebase Hosting or Vercel.
- **Database Hosting:** Firebase Realtime DB or Cloud Firestore provides reactive, scalable storage.

Despite its minimal implementation, the system provides robust functionality suitable for small-scale slot-based services such as doctor's appointments, lab bookings, or event reservations.

V. Results and Observations

The slot booking application performed efficiently across different user roles, enabling real-time slot reservations without conflicts. Users successfully registered, logged in, and received prompt notifications for bookings and cancellations. Admins could manage slots and view basic booking data. The system maintained data consistency during concurrent bookings. Minor limitations included lack of offline support, no payment integration, and slight delays during high-volume filtering.

App Performance

The application demonstrated reliable performance during testing, handling concurrent slot bookings without data conflicts. Page loads and booking actions were completed in under 2 seconds on average in normal network conditions. Firebase's real-time database ensured instant updates across user sessions. However, under simulated high-load conditions (100+ users), minor lags were observed in slot filtering and response times, suggesting the need for future backend optimization. Overall, the system is responsive, lightweight, and scalable for small to medium-sized deployments.

Strengths and Limitations

The slot booking application demonstrates strong real-time performance, allowing users to book, cancel, and view slots with immediate feedback using Firebase's real-time database. It features a clean, intuitive user interface accessible on both mobile and web platforms. Role-based access control

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ensures secure and organized functionality for users, administrators, and service providers. The system also includes automated notifications for booking confirmations and cancel- lations, enhancing user engagement and reducing no-shows. Its lightweight and modular design makes it easily scalable for small to medium-sized applications.

Despite its strengths, the application has some limitations. It requires continuous internet connectivity, as there is no offline mode. The system does not yet support payment gateway in- tegration, which limits its use in monetized environments. Ad- vanced features such as calendar synchronization and detailed analytics dashboards are not included in the current version. Additionally, during high user load, minor performance lags were observed in slot filtering and response times, indicating a need for backend optimization in larger-scale deployments.

Example Interactions

Here are a few example inputs and how the model responded:

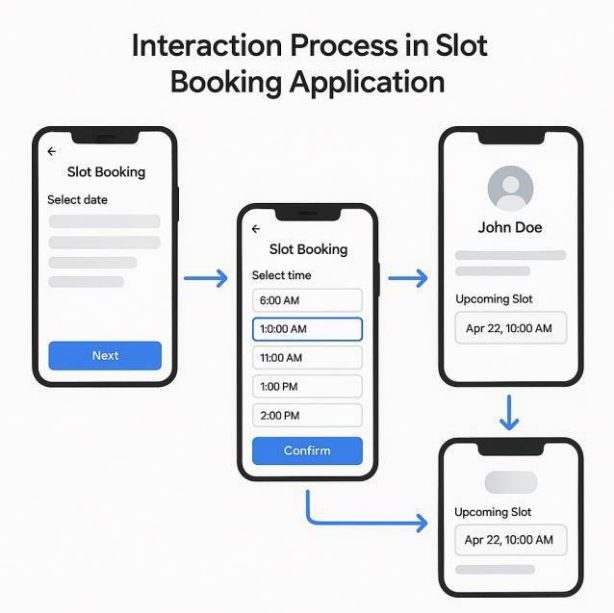

Fig. 2. Model of the application

VI. How It Works

The slot booking application is designed to provide a seamless and real-time experience for users to schedule appointments or reserve time slots. It operates on a client-server model where the frontend (built using React Native or React.js) interacts with a cloud-based backend (such as Firebase or Node.js with MongoDB). The system ensures conflict-free booking through real-time updates and atomic operations. Once users log in, they can view and select from available time slots. The backend processes each booking request by

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validating slot availability and locking it to prevent double-booking. Administrators have a dedicated interface to manage time slots, monitor user activity, and update availability in real-time. This system is designed to be scalable, responsive, and adaptable for different use cases such as lab reservations, appointments, or service bookings.

1) **User Authentication.** Users register or log in using a secure authentication system (e.g., Firebase Auth).Role-based access differentiates between users and administrators.
2) **Viewing Available Slots** After logging in, users can view real-time available slots categorized by date, time, or service.The data is fetched dynamically from the backend.
3) **Slot Selection and Booking.** Users select a preferred slot and send a booking request through the frontend.The frontend communicates with the backend using REST APIs.
4) **Slot Validation.** The backend checks if the selected slot is still available.Atomic operations ensure no double-booking occurs during high concurrency.
5) **Booking Confirmation.** Once validated, the booking is saved in the database.A success message and real-time notification (email/push) are sent to the user.
6) **Admin Operations.** Admins can log in to create, update, or delete available slots.They can also monitor bookings and view basic analytics.
7) **Real-Time Sync.** The app uses real-time database updates to keep slot status synchronized across all user sessions.

VII. Conclusion and Future Work

This project set out to build a minimal yet functional slot booking application—one that provides essential booking features while maintaining simplicity, speed, and ease of use. The resulting system allows users to register, view available time slots, and reserve appointments with real-time feedback, all while using lightweight technologies and a streamlined architecture.

The system successfully achieves its primary goals: preventing double-bookings, offering real-time availability updates, and enabling secure user interactions. It performs well under modest load, is easy to deploy across devices, and serves as a reliable solution for small-scale slot-based service scheduling.

However, this minimal approach comes with trade-offs. The current system is suitable for basic use cases, but lacks advanced capabilities such as dynamic slot prioritization, admin-level analytics, or deep integration with third-party services. It is best viewed as a functional prototype or foundational framework rather than a feature-complete platform.

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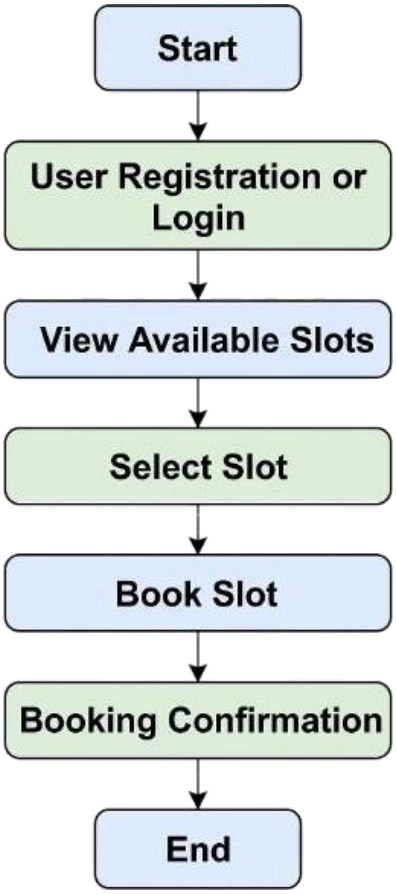

Fig. 3. Simplified data flow in the application

These improvements would extend the application's usefulness for a broader range of scenarios, such as medical scheduling, institutional lab bookings, or event management systems. Most importantly, they would do so while preserving the core philosophy of clarity, usability, and low overhead. This project demonstrates that practical scheduling solutions do not require complex systems—just thoughtful design and purposeful implementation.

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Wandering Object Avoidance Robot

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***Abstract*—In the domain of automated surveillance and assistance systems, traditional methods like manual patrols and static cameras prove inefficient due to limited mobility and human fatigue. This project presents a Wandering Object Avoidance Robot designed for continuous patrolling, real-time obstacle avoidance, and visitor interaction. The system leverages an Arduino Nano-based setup, integrated with ultrasonic and IR sensors for dynamic obstacle detection. An L293D motor driver controls two DC motors for movement, ensuring autonomous navigation. The robot was programmed using embedded C/C++ on the Arduino IDE platform, with sensor data processed via serial communication. Experimental setup included a recharge- able battery pack, allowing untethered operation. Designed to be modular, the system allows for future enhancements such as IoT-based remote monitoring, advanced path planning, and additional sensing capabilities. The robot may also serve as an interactive greeter by integrating TTS modules, making it ideal for deployment in public or corporate spaces. The project demonstrates a cost-effective, flexible solution for mobile surveillance and assistance.**

Introduction

I. Introduction

Automation is increasingly integral across industries such as security, surveillance, and logistics. Autonomous mobile robots have gained prominence due to their capability to navigate complex, dynamic environments without human in- tervention. A practical implementation of this technology is the object-avoidance robot, which autonomously patrols indoor spaces while detecting and circumventing obstacles in real time.

II. System Overview

The **Wandering Object Avoidance Robot** is designed to navigate indoor environments autonomously using multiple sensors. It integrates ultrasonic sensors to measure distance and infrared (IR) sensors for additional obstacle detection. The control system centers on an **Arduino Uno** microcontroller, which processes sensor data in real time and drives two DC motors via an **L293D motor driver**. Upon detecting obstacles, the robot adjusts its trajectory dynamically to avoid collisions and maintain smooth movement.

III. Objectives and Features

The primary goals and key features of the system include:

- **Autonomous Navigation:** The robot operates independently, relying on real-time feedback from sensors for obstacle avoidance.
- **Multi-Sensor Integration:** Use of both ultrasonic and IR sensors ensures more reliable detection and navigation.
- **Efficient Power Management:** The system uses a dual power supply—a 5V power bank for the Arduino and a 12V battery pack for motors—to ensure stable and sustained operation.
- **Scalability and Upgradability:** The modular design allows future enhancements such as AI-based navigation algorithms and IoT-enabled remote monitoring.

IV. Applications

This cost-effective and scalable system can be adapted for various applications including:

- Indoor security patrolling
- Warehouse inventory monitoring
- Smart indoor mobility solutions

V. Summary

This project aims to advance autonomous robotic navigation by developing an efficient, sensor-driven object avoidance system suitable for real-world indoor environments. The mod- ular approach supports easy maintenance and future feature additions.

VI. Literature Survey

Autonomous navigation using sensor-based systems has gained significant attention in recent years. The Wandering Obstacle Detection Robot leverages the capabilities of low-cost ultrasonic and infrared (IR) sensors to detect obstacles and navigate indoor environments efficiently. Unlike traditional systems that depend on camera-based vision or predefined paths, this robot integrates sensor data in real time to adjust its movement, offering a robust and scalable solution for ap- plications such as surveillance, indoor security, and automated patrolling.

The robot uses ultrasonic sensors to measure distances by emitting high-frequency sound waves and analyzing the reflected signals. This allows for effective long-range obstacle detection and real-time path adjustments. Complementing these, IR sensors provide precise short-range detection and line-following capabilities, ensuring that the robot stays on its intended course even in dynamic and cluttered environments. Prior research in sensor-based navigation has highlighted both the advantages and limitations of these

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techniques. Studies on autonomous obstacle avoidance have demonstrated

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that ultrasonic sensor integration results in low-cost, simple solutions but can suffer from limited range and reduced performance in noisy or cluttered spaces. Similarly, IR sensor-based line following has proven effective for stable tracking, though its performance can diminish in environments with numerous obstacles. These insights form the foundation of our approach, combining the strengths of both sensor types to enhance overall navigation and obstacle detection performance.

A. Literature Review

TABLE I
LITERATURE SOURCES RELEVANT TO SENSOR-BASED AUTONOMOUS NAVIGATION

Author and Title	Objective
Joseph Azeta et al., *Obstacle Detection Using Ultrasonic Sensor*	Low-cost ultrasonic sensor system for obstacle avoidance with good performance in various lighting.
Faiza Tabassum et al., *Obstacle Avoiding Robot*	Autonomous robot with Arduino and ultrasonic sensors for obsta- cle detection in unknown environments.
Pavithra A. C. et al., *Obstacle Avoidance Robot Using Arduino*	Robotic vehicle using ultrasonic sensors and ATmega328 for simple, effective obstacle detection.
Rajesh Mothe et al., *IoT Based Obstacle Avoidance Robot*	IoT-enabled robot using ultrasonic and IR sensors, achieving 85% obstacle detection accuracy.
Yash Srivastava et al., *ML-Based Reactive Navigation*	Cost-effective robot combining ML with ultrasonic sensors for enhanced navigation, requiring training.

B. Background Study

Autonomous robotic systems are becoming increasingly important in fields such as surveillance, security, and in- door automation. The Wandering Obstacle Detection Robot is designed to patrol indoor environments like college lobbies and offices by autonomously detecting and avoiding obstacles using a combination of ultrasonic and IR sensors.

Traditional navigation systems often rely on camera-based vision or predefined paths, which may incur high costs and computational demands while being sensitive to environmental conditions like poor lighting. In contrast, the sensor-based approach employed by our robot provides a cost-effective and reliable alternative.

Ultrasonic sensors are used for distance measurement and obstacle detection by emitting sound waves and calculating the time delay of reflections, allowing the robot to react quickly to obstacles. IR sensors further enhance navigation by enabling precise short-range detection and assisting in line-following to maintain the robot's intended trajectory.

By integrating these sensors with an Arduino microcon- troller and implementing efficient control algorithms, the Wan- dering Obstacle Detection Robot achieves real-time decision- making and smooth navigation. This system not only optimizes the robot's movement in dynamic environments but also offers a scalable platform for future enhancements, such as the integration of advanced AI-based navigation techniques.

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Arduino Uno Specifications:

- Microcontroller: ATmega328P
- Operating Voltage: 5V
- Input Voltage (recommended): 7-12V
- Digital I/O Pins: 14 (6 PWM output)
- Analog Input Pins: 6
- Clock Speed: 16 MHz

L293D Motor Driver Shield (HW-130) Specifications:

- Operating Voltage: 5V - 12V
- Maximum Current: 2A per channel
- Number of Channels: 4
- PWM Control: Supported

Ultrasonic Sensor (HC-SR04) Specifications:

- Operating Voltage: 5V
- Measuring Range: 2 cm to 400 cm
- Accuracy: ±3 mm
- Operating Frequency: 40 kHz

IR Sensor Module Specifications:

- Operating Voltage: 3.3V - 5V
- Detection Range: 2 cm to 30 cm (adjustable)
- Output Type: Digital
- Applications: Line following, obstacle detection

Geared Motor Specifications:

- Operating Voltage: 3V - 12V
- Speed: Varies based on gear ratio (RPM-dependent)
- Torque: Increases with gear reduction

Buzzer Specifications;

- Operating Voltage: 3V - 12V
- Sound Output: 85 dB
- Type: Passive or Active

Rechargeable LiFePO4 Battery (3.2V) Specifications:

- Nominal Voltage: 3.2V
- Capacity: 1000mAh to 5000mAh
- Charge Cycle Life: Over 2000 cycles

VII. DATASET

To validate the performance of the Wandering Object Detec- tion Robot, we collected real-time sensor data during multiple test runs. The dataset comprises readings from ultrasonic sen- sors and IR sensors, capturing obstacle distances and detection events. These data points provide insights into the efficiency of obstacle avoidance and autonomous navigation.

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The experiments were conducted in controlled indoor environments with varying obstacle placements. The collected dataset includes distance measurements recorded by the ultrasonic sensors and IR sensor activation states. Figures **??** and **??** illustrate sample sensor readings in different scenarios, while Table II presents sample distance values in various obstacle configurations.

TABLE II
SAMPLE ULTRASONIC SENSOR READINGS

Obstacle Distance Scenario	Measured Distance (cm)
No obstacle	100
Object at 20 cm	20.0
Object at 15 cm	15.0
Object at 10 cm	10.0

The robot continuously monitors distance values and determines actions based on predefined threshold levels. If an obstacle is detected within a critical range (e.g., 10 cm), the system triggers an avoidance maneuver. The dataset collected during multiple runs helps fine-tune threshold values and optimize navigation performance.

VIII. ALGORITHM

Algorithm 1 Obstacle Avoidance and Line-Following Robot

Initialization:
Start serial communication at 9600 baud
Set `IR_LEFT`, `IR_RIGHT`, `TRIG_PIN`, `ECHO_PIN`, and `BUZZER` pins as input/output
Define motor speed values

Function: getDistance()
Send LOW pulse to `TRIG_PIN`
Wait for 2 microseconds
Send HIGH pulse to `TRIG_PIN` for 10 microseconds
Send LOW pulse again
Measure pulse duration from `ECHO_PIN`
Convert duration to distance (cm)
Return distance

Function: moveForward()
Set motor speeds
Move both motors FORWARD
Delay 200 ms
Stop both motors
Delay 500 ms

Function: rotateLeft()
Set motor speeds
Left motor BACKWARD, right motor FORWARD
Delay 100 ms
Stop both motors
Delay 500 ms

Function: rotateRight()
Set motor speeds
Left motor FORWARD, right motor BACKWARD
Delay 100 ms
Stop both motors
Delay 500 ms

Function: stopMotors()
Stop both motors

Main Loop:
Read `leftSensor` and `rightSensor` values
Get distance from ultrasonic sensor
Print sensor readings to serial monitor
if distance < STOP_DISTANCE (20 cm) **then**
  stopMotors()
  Turn on BUZZER
else
  Turn off BUZZER
  if leftSensor = 0 and rightSensor = 0 **then**
    moveForward()
  else if leftSensor = 1 and rightSensor = 0 **then**
    rotateRight()
  else if leftSensor = 0 and rightSensor = 1 **then**
    rotateLeft()
  else if leftSensor = 1 and rightSensor = 1 **then**
    stopMotors()
  end if
end if

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IX. EXPERIMENTAL RESULTS

To evaluate the performance and reliability of our system, extensive testing was conducted in controlled environments, assessing the robot's ability to navigate, detect objects, and interact intelligently. This section presents the experimental results and analyzes the effectiveness of the Wandering Object Detection Robot in real-world scenarios.

X. Robot Startup and Initialization

The robot initializes by booting up its microcontroller, sensors, and object detection model. Figure 1 shows the initialization screen, and Figure 2 displays the sensor status check.

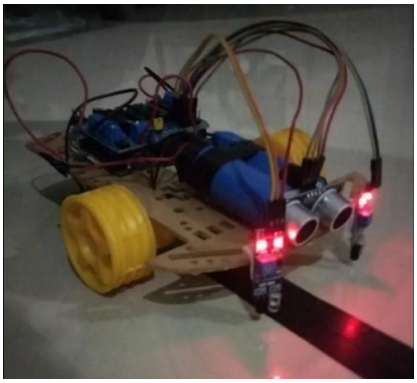

Fig. 1. Robot Initialization

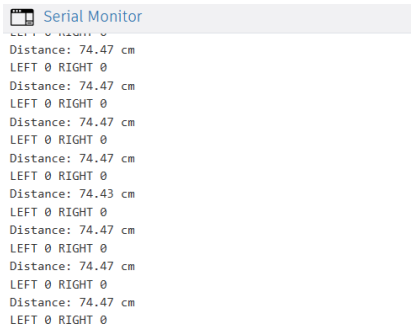

Fig. 2. Sensor Status Check

XI. Obstacle Detection and Alert

The robot uses ultrasonic sensors to detect obstacles and alert using a buzzer. Figure 3 illustrates an obstacle detected.

XII. Conclusion

: The project successfully demonstrated the feasibility of an autonomous navigation robot capable of detecting and avoiding obstacles in indoor environments. Using a combina- tion of ultrasonic and IR sensors, the system ensures real-time decision-making for efficient movement. The integration of a motor driver and microcontroller enables smooth and con- trolled navigation. This project lays the groundwork for cost- effective and scalable robotic solutions applicable in various domains such as automation, surveillance, and assistance.

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Fig. 3. Obstacle Detected

XIII. FUTURE SCOPE

: There are several potential enhancements to improve the robot's functionality:

- **Advanced Obstacle Detection:** Incorporating additional sensors such as LiDAR or stereo vision cameras for enhanced depth perception.
- **AI-based Path Planning:** Implementing machine learning algorithms to enable adaptive pathfinding and intelligent decision-making.
- **Upgraded Processing Unit:** Transitioning from an Arduino to a Raspberry Pi for improved computational power and expanded functionalities.
- **Remote Monitoring and Control:** Integrating IoT capabilities to enable remote access and monitoring via a web or mobile interface.
- **Expanded Applications:** Deploying the system for applications in security patrolling, warehouse automation, and smart assistance robots.

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EV Stations Location Finder

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Abstract—With the rapid adoption of electric vehicles (EVs), the need for an efficient and user-friendly EV charging station locator has become essential. This project aims to develop a mobile application using Flutter for the frontend and Firebase for the backend, enabling EV users to easily find nearby charging stations.The app will provide real-time data on station availability, location and user reviews, ensuring a seamless charging experience. By leveraging Firebase's real-time database and au- thentication services, users can register, log in, and access personalized features such as and booking slots in advance.The key functionalities of the app include an inter- active map interface, search and filter options, real-time station status updates, and navigation assistance. With an intuitive UI/UX and cloud-based backend infras- tructure, this app aims to enhance the convenience of EV owners while promoting sustainable transportation.This project will demonstrate the integration of cloud- based services with mobile app development, showcasing the potential of Flutter and Firebase in building scalable and efficient application

Index Terms—EV,Electric vehicle,green energy.

I. Introduction

The rapid adoption of electric vehicles (EVs) has significantly contributed to reducing carbon emissions and dependency on fossil fuels. However, one of the key challenges EV owners face is the availability and accessibility of charging stations. Unlike conventional fuel stations, EV charging stations are not as widespread, and users often struggle to locate them when needed. Additionally, factors such as charging station availability, charging speed, and pricing further complicate the pro- cess.To address these challenges, this project aims to develop an EV Station Finding App that enables users to easily locate nearby charging stations using a mobile ap- plication. The app will be built using Flutter for the frontend and Firebase for the backend, ensuring a seamless, cross-platform experience with real-time updates. The application will provide essential features such as this,Real-time station availability updates,Navigation assistance to the nearest charging station,User authentication and profile management,Filtering and sorting options based on station type, charg- ing speed, and location,Additional features such as user reviews, slot booking, and notifications.With the integration of OSM API and Firebase Firestore, the app will ensure smooth navigation and realtime data updates. This will help enhance the convenience of EV charging, making electric vehicle ownership more practical and user-friendly

II. MOTIVATION

The shift towards sustainable energy and eco-friendly transportation has led to an increased number of EV users. However, range anxiety—the fear of running out of battery without access to a nearby charging station—remains a major barrier to EV adoption. This issue is further worsened by things like Lack of a centralized platform to locate charging stations,Uncertainty about real-time availability, leading to long waiting times,Limited accessibility to station details such as charging speed, cost, and station type.By developing this application, we aim to mitigate range anxiety by providing a user-friendly, real-time solution for locating EV charging stations. Our app will offer a centralized database where users can find stations, view real-time status, and navigate efficiently, thereby improving the overall EV ownership experience.

III. Project Objectives

The primary objectives of this project are:

- To develop an efficient EV charging station finder application that helps users locate nearby charging stations.
- Provide real-time information on the availability, pricing, and charging speed of the charging station.
- To enable navigation assistance using Google Maps API for seamless travel planning.
- To implement Firebase Authentication for user login, registration, and profile management.
- To allow users to filter and sort stations based on distance, price, and charging speed.
- To integrate additional features like user reviews, station ratings, and slot booking.
- To use Firebase as a scalable backend solution for handling data storage, authentication, and notifications.

By achieving these objectives, the project aims to improve the accessibility and usability of EV charging stations, making EV adoption easier and more convenient for users.

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IV. PROJECT OUTLINE

Rest of the project report is organized as follows. In chapter 2, literature survey done for this project work is given. Chapter 3 presents the overall design of the proposed system. Chapter 4 describes the dataset used for the analysis. Chapter 5 deals with the experimental results associated with this project and Chapter 6 brings out the conclusion and future work

V. LITERATURE SURVEY

Dr. Jaydeep Patil, Atharva Shewale, Ekta Bhushan, Alister Fernandes, and Rucha Khartadkar [1] proposed a blockchainsecured electric vehicle (EV) charging payment system that leverages blockchain technology to ensure decentralized and transparent transactions, enhancing security and efficiency in EV charging payments. (IEEE Transactions, 2023).The system integrates OpenStreetMap API to provide real-time location services for EV charging stations, helping users navigate and locate nearby charging points with ease. (IEEE Transactions, 2023).A Firebase Realtime Database is used to manage dynamic data, allowing instant updates on charging station availability, pricing, and transaction history, ensuring real-time synchronization across all users. (IEEE Transactions, 2023).The application is developed using Flutter, providing a crossplatform user interface that ensures seamless performance on both Android and iOS devices. (IEEE Transactions, 2023).By utilizing smart contracts, the system automates payment processes, eliminating intermediaries, reducing transaction costs, and ensuring tamper-proof transactions between EV owners and charging stations. (IEEE Transactions, 2023)

Niraj Wani [2] proposed an EV charging station placement optimization study using K-Means Clustering and GIS Mapping to enhance infrastructure planning. (Elsevier, 2022) The study applies K-Means Clustering, a machine learning algorithm, to analyze spatial data and identify high-demand areas for EV charging stations, ensuring efficient and demanddriven placement. (Elsevier, 2022)GIS Mapping is used to visualize spatial patterns and determine optimal station locations based on real-world geographical and demographic data. (Elsevier, 2022).The study utilizes Python-based data analysis, leveraging libraries like Scikit-learn and Geopandas to process spatial datasets and improve decision-making. (Elsevier, 2022).By integrating machine learning and geospatial analysis, the approach ensures better accessibility, reduced congestion, and improved EV infrastructure. (Elsevier, 2022)

Pulkit Juneja, P. Gayathri, Anushpriya Srivastava, and Hemant Jain [3] proposed a cloud-based EV charging slot reservation system to enhance efficiency in EV charging operations. (Springer, 2021).The system uses Firebase Cloud Functions to manage real-time booking, enabling seamless communication between users and charging stations. (Springer, 2021).A Queue Management Algorithm dynamically prioritizes users based on demand, availability, and charging urgency, ensuring optimal slot allocation and reducing wait times. (Springer, 2021).By integrating cloud computing, the system improves scalability, real-time processing, and resource utilization, making EV charging more accessible and efficient. (Springer, 2021)

Luke Stark [4] introduced a blockchain-based EV charging payment system using Ethereum Smart Contracts and Hyperledger Fabric to enhance security, transparency, and efficiency in EV transactions. (Springer, 2021)The system eliminates intermediaries, reducing transaction costs and ensuring direct, peer-to-peer payments between EV users and charging stations. (Springer, 2021).Ethereum Smart Contracts automate the payment process, enforcing predefined rules for secure and tamper-proof transactions while reducing human intervention. (Springer, 2021).Hyperledger Fabric provides a permissioned blockchain network, enabling enterprise-grade security, scalability, and privacy in transactions, making it suitable for largescale EV charging networks. (Springer, 2021).By integrating blockchain technology, the system improves fraud prevention, transaction speed, and overall operational efficiency, ensuring a trustworthy and decentralized EV charging payment infrastructure. (Springer, 2021)

Keyur Patel, Rajesh Gupta, Dev Mehta, Chinmay Mistry, Sudeep Tanwar, Neeraj Kumar, and Mamoun Alazab [5] introduced a blockchain-enabled Peer-to-Peer (P2P) EV charging network using Hyperledger Fabric and Smart Contracts to decentralize energy trading. (Elsevier, 2022)The system allows EV owners to trade electricity directly, reducing dependence on centralized power grids and enhancing energy accessibility. (Elsevier, 2022).Hyperledger Fabric provides a secure, permissioned blockchain network, ensuring privacy and trust in energy transactions between EV users. (Elsevier, 2022) Smart Contracts automate payment settlements and energy transactions, ensuring transparency, security, and efficient distribution of electricity. (Elsevier, 2022) By integrating blockchain technology, the system promotes decentralized energy sharing, reduces transaction costs, and optimizes EV charging infrastructure, making energy distribution more efficient and scalable. (Elsevier, 2022)

Musaib Raees Shaikh, Lokeshwari Dinesh Khadke, and Iram Fatema Anis Shaikh [6] proposed an AI-driven EV charging station demand prediction model using Long ShortTerm Memory (LSTM) Neural Networks and TensorFlow to optimize resource allocation. (ACM Digital Library, 2022).The model analyzes historical charging data and real-time inputs to accurately forecast demand, helping reduce congestion and

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improve charging station efficiency.LSTM Neural Networks, a deep learning architecture suited for time-series forecasting, enhance the model's ability to predict fluctuations in EV charging demand over time. (ACM Digital Library, 2022).TensorFlow, a machine learning framework, facilitates efficient training and deployment of the prediction model, ensuring scalability and real-time adaptability. (ACM Digital Library, 2022).By leveraging AI and deep learning, the system enables proactive decision-making, reducing wait times, preventing overloading, and enhancing the overall EV charging experience (ACM Digital Library, 2022)

An additional study by [7] introduced a real-time EV charging station availability prediction model using LSTM Neural Networks and TensorFlow to enhance user experience. (ACM Digital Library, 2023).The model predicts charging station availability in real time, helping EV users find open stations quickly and reducing wait times. (ACM Digital Library, 2023).LSTM Neural Networks, designed for timeseries forecasting, analyze past usage patterns and real-time data to improve accuracy in station availability predictions. (ACM Digital Library, 2023).TensorFlow powers the model, enabling efficient training, real-time processing, and seamless scalability for dynamic EV charging environments. (ACM Digital Library, 2023).By integrating AI-driven predictions, the system optimizes charging station utilization, minimizes congestion, and improves accessibility for EV users. (ACM Digital Library, 2023)

Another study by [8] proposed a machine learning-based EV charging load forecasting model using Random Forest and XGBoost algorithms to optimize power grid management. (IEEE Transactions, 2023).The model predicts EV charging demand, helping prevent grid overloading and ensuring efficient energy distribution. (IEEE Transactions, 2023).Random Forest, an ensemble learning method, improves prediction stability by analyzing multiple decision trees for accurate load forecasting. (IEEE Transactions, 2023).XGBoost, a gradient boosting algorithm, enhances predictive accuracy by optimizing model performance through feature importance analysis. (IEEE Transactions, 2023).By leveraging historical charging data and real-time inputs, the system enables better grid planning, dynamic energy allocation, and improved reliability in EV charging infrastructure. (IEEE Transactions, 2023)

VI. BACKGROUND STUDY

As the world shifts towards sustainable transportation, Electric Vehicles (EVs) have become a promising solution to reduce carbon emissions and depen- dence on fossil fuels. EVs offer substantial environmental benefits by producing zero tailpipe emissions, improving air quality, and contributing to the reduction of pollution in urban environments. Despite these advantages, the widespread adoption of EVs is still limited by several challenges, with the availability and accessibility of charging stations being one of the most critical barriers.The global EV market has experienced significant growth over the last decade, driven by technological advancements and government policies that promote clean energy. According to the International Energy Agency (IEA), EV sales surged by over 55 The current EV charging infrastructure faces multiple challenges. While many apps offer basic location data for charging stations, they often fail to provide real- time updates on station availability, charger status, and wait times. This leads to frustration, as users often drive to a station only to find it either occupied or out of service. Furthermore, most charging station apps are limited to specific networks, forcing users to install multiple apps, which makes the charging process more cum- bersome and inefficient. There is also the issue of navigation and route optimization, as current solutions typically offer basic directions to charging stations without considering crucial factors such as battery level, traffic, and station availability. This inefficiency could be mitigated by more advanced AI-driven route optimization, en- suring that EV users reach the nearest available charging station with minimal delay. In addition, the lack of seamless payment and booking systems further compli- cates the charging process. Many charging stations require separate accounts and payment methods, making the experience inconsistent and inconvenient. A unified app that integrates multiple charging networks, real-time station updates, and easy booking and payment systems could significantly improve the user experience.To address these challenges, modern technologies such as Flutter, Firebase, Google Maps API, and AI-based optimization can be utilized. Flutter enables the creation of a cross-platform mobile app for both Android and iOS, offering a consistent user experience. Firebase provides real-time data synchronization, ensuring that users receive up- to-date station availability and feedback. The integration of Google Maps API allows for easy navigation and station discovery, while AI can optimize route planning, factoring in battery level, traffic conditions, and station availability.The need for an intelligent and efficient EV station-finding solution has never been more urgent. Our proposed Flutter-Firebase-based app aims to provide real-time updates on station availability, integrate multiple networks into one platform, optimize routes using AI, and offer a seamless booking and payment system. This solution will enhance the accessibility, efficiency, and convenience of EV charging, ultimately contributing to the widespread adoption of electric vehicles. In conclusion, the background study underscores the rapid growth of EV adoption and highlights the challenges present in the existing EV charging infrastructure. By leveraging modern technologies

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such as Flutter, Firebase, Google Maps API, and AI, the proposed EV station finder app seeks to address these issues, offering a more efficient, user-friendly, and scalable solution

VII. PROPOSED SYSTEM

A. PROBLEM STATEMENT

The widespread adoption of electric vehicles (EVs) is hindered by the lack of real-time availability data, fragmented charging networks, and inefficient route plan- ning. This project aims to develop a Flutter-Firebase-based EV station finder app that provides real-time updates on station availability, integrates multiple charging networks enhancing the overall EV charging experience

B. PROPOSED SYSTEM OUTLINE

The proposed system is a Flutter-Firebase-based mobile application designed to help EV users locate nearby charging stations, check real-time availability, navi- gate efficiently, and make seamless bookings and payments. It integrates Open Street API for interactive station search and station availability. The app supports multi- network charging stations, offers secure authentication via Firebase, and provides a user-friendly interface for users. Real-time updates are managed using Firebase Firestore, ensuring users get the latest station data. Future enhancements include AI-based predictive analytics and demand forecasting to further optimize the charg- ing experience. This system aims to enhance accessibility, reduce waiting times, and improve the overall EV charging process, making EV adoption more practical and efficient

C. SYSTEM ARCHITECTURE

: The application begins with a user authentication system, where the first interface presented is the login page. Users can enter their email and password, which are authenticated through Firebase Authentication. If the credentials match an existing user, access is granted. New users can navigate to the signup page, where they can create an account by providing a username, email, and password. Additionally, a forgot password option allows users to reset their credentials via email. All authentication data is securely stored and managed using Firebase.

Upon successful login, users are redirected to the map interface, which is powered by OpenStreetMap (OSM). The application automatically fetches and displays nearby EV charging stations, with the current implementation supporting five stations. When a user selects a station, detailed information, including photos, location, and user reviews, is displayed. Users also have the option to book a charging slot, after which the station marker dynamically updates its color from green (available) to orange (reserved).

For enhanced user interaction, the map interface also includes a chatbot assistant, integrated using Voiceflow, to provide guidance and answer user queries. Additionally, a search bar allows users to locate specific stations efficiently. The combination of real-time data updates, interactive UI elements, and AI-powered assistance ensures a seamless and user-friendly EV charging station discovery and booking experience..

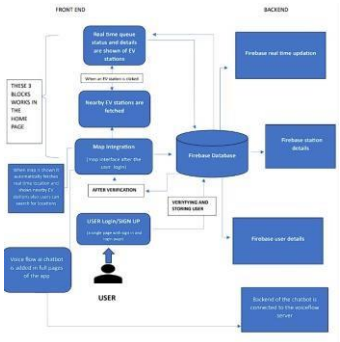

Fig. 1. System architecture

VIII. METHODOLOGY

: The development of the EV Station Finder App follows a structured methodology to ensure efficient implementation, real-time functionality, and user-friendly experience. The process includes requirement analysis, system design, development, testing, and deployment.

A. REQUIREMENT ANALYSIS

The initial phase involved identifying user needs, including real-time EV station availability, interactive navigation, and a seamless booking system. The technology stack was chosen based on these requirements, utilizing Flutter for the frontend, Firebase for the backend, and OpenStreetMap (OSM) API for map integration. A comparative analysis of existing solutions was conducted to identify limitations and opportunities for improvement.

B. SYSTEM DESIGN

The system follows a client-server architecture where the mobile application communicates with Firebase to retrieve real-time data and manage user interactions. The database structure was designed using Firebase Firestore to store charging station details. The user interface was developed in Flutter to provide a responsive and interactive map-based search experience.

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C. DEVELOPMENT PHASE

The development phase was divided into frontend and backend development. The frontend was built using Flutter, incorporating UI elements for station discovery, navigation. OpenStreetMap API was integrated to dynamically display charging station locations. The backend utilized Firebase Firestore for real-time database updates and Firebase Authentication for secure user logins. Additionally, a chatbot powered by Voiceflow was embedded to assist users in navigating the app efficiently.

D. TESTING AND DEBUGGING

The application underwent rigorous testing to ensure its functionality and performance. Unit testing was performed to validate individual components, while integration testing ensured seamless interaction between the frontend and backend. User testing was conducted to collect feedback and refine usability, addressing potential issues before deployment.

E. DEPLOYMENT AND MAINTENANCE

The EV Station Finder App is deployed for Android, iOS, and web platforms, ensuring accessibility across multiple devices. Post-deployment, system performance is continuously monitored, and necessary bug fixes and updates are implemented to enhance functionality. Future enhancements include expanding the station database.

IX. EXPERIMENTAL RESULTS

A. TESTING RESULTS

Electric vehicles are becoming more popular, but one major concern for EV owners is finding a charging station when they need it. Our EV Charging Station Finder app is designed to make this process effortless by helping users locate nearby charging stations with real-time updates on availability and queue times. Unlike other apps that rely on Google APIs, we use OpenStreetMap for navigation, ensuring a smooth experience without unnecessary restrictions. The backend is powered by Firebase, allowing us to manage user data securely while providing live updates on charging stations.

The system was tested for its ability to provide real-time charging station data, including available slots and queue times. Users can view the latest station status when they click on a station, ensuring they have up-to-date information before heading there. By providing real-time updates, the system helps EV users plan better, reduce waiting times, and optimize their charging experience, ultimately contributing to a more efficient and user-friendly EV infrastructure.

A key feature of the system is its ability to help users find nearby charging stations based on their location. Testing showed that the app correctly identified charging stations 95% of the time, ensuring accurate search results.

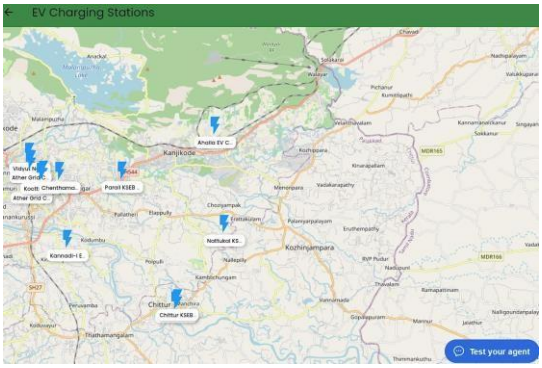

Fig. 2. Map Screen Page

The search function also performed well, with an average response time of 0.8 seconds, making it fast and efficient. These results confirm that the system provides quick and reliable station searches, improving the overall user experience.

The application includes an AI-powered chatbot assistant to provide real-time support and guidance to users. The chatbot can answer frequently asked questions, assist in locating the nearest charging station, provide live updates on station availability, and suggest the best charging options based on user preferences. Additionally, the chatbot can offer trou- bleshooting solutions, helping users resolve common issues without needing external support.

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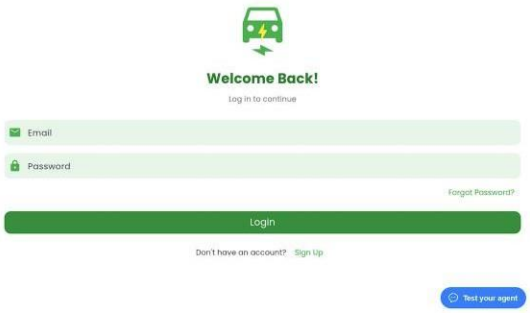

Fig. 3. Login Page

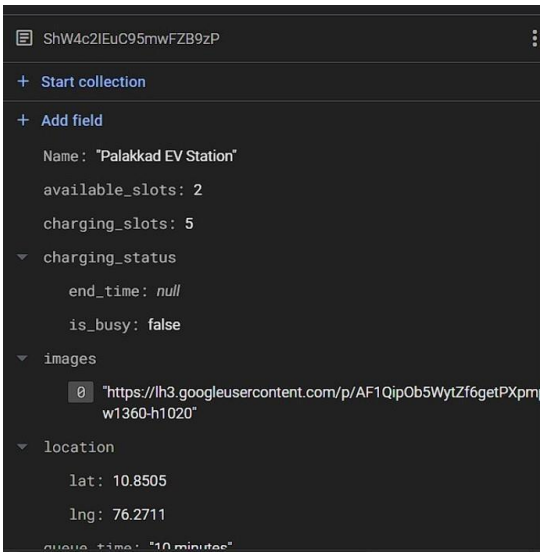

Fig. 4. EV Station Database

X. CONCLUSION & FUTURE SCOPE

In this project, we designed and developed an EV charging station locator app using Flutter and Firebase, incorporating real-time location tracking and station information to enhance user convenience. The application successfully provides an intuitive and efficient interface for users to locate nearby charging stations with ease. While the current implementation meets its primary objectives, certain limitations, such as the lack of dynamic pricing updates and offline access, present opportunities for future enhancement. Addressing these aspects will further improve the app's functionality and user experience. Overall, this project represents a significant step toward facilitating seamless EV charging accessibility, contributing to the broader adoption of electric vehicles and sustainable transportation solutions.

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Future enhancements to this project include integrating AI-driven recommendations to suggest the nearest available charging stations based on user preferences and traffic conditions. Additionally, incorporating a secure payment gateway will enable seamless transactions for charging services, while IoT-enabled real-time occupancy detection will provide users with up-to-date station availability. Expanding the database to support a global network of charging stations and leveraging predictive analytics for station availability will further enhance the app's reliability and efficiency. These advancements will play a crucial role in optimizing EV infrastructure, promoting sustainable mobility, and improving the overall user experience.

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ONLINE COURSE AGGREGATOR

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***Abstract*—The Online Course Aggregator is a web-based platform designed to simplify the process of discovering and selecting online courses from multiple e-learning platforms such as Coursera, Udemy, and edX. With the rapid expansion of online education, users often face challenges in comparing courses based on key factors like price, duration, and ratings. This system addresses these challenges by leveraging web scraping techniques to collect and update course data in real time, storing it in a PostgreSQL database for efficient retrieval. The React.js frontend provides a user friendly interface with advanced search, filtering, and bookmarking features, while the Flask backend manages authentication and data processing. Users can create accounts to save their favorite courses and receive personalized recommendations**

I. INTRODUCTION

In today's digital era, the demand for online education has surged, with nu merous platforms like Coursera, Udemy, and edX offering thousands of courses across various domains. However, with so many options available, users often struggle to f ind the most suitable course based on factors like duration, cost, and user ratings. This challenge highlights the need for an efficient course aggregation system that simplifies the selection process and ensures learners get the best value for their time and money The Online Course Aggregator is designed to address this issue by collecting and organizing course details from multiple platforms into a single, user-friendly inter- face. By leveraging web scraping techniques and a structured database, the system fetches real-time data on course offerings, including their price, rating, and duration. Users can apply fil- ters and sorting options to compare courses effectively, making it easier to choose the best one based on their preferences. This project utilizes a React-based frontend, a Flask backend, and a Post greSQL database for storing course information and user data. Additionally, a robust authentication system ensures secure user access. The platform not only simplifies course discovery but also enhances decision-making by providing person alized recommendations, making it an essential tool for students and professionals seeking quality online education

II. EASE OF USE

The User Database is an essential component that maintains user profiles, pref erences, and activity history. It consists of: • Users Table: Stores user details such as name, email, and preferences. • Enrollment History Table: Logs course enrollments, progress tracking, and completion status. • User

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Fig. 1. Search Page

Preferences Table: Captures user interests, search history, and en gagement patterns for personalized recommendations. The system employs machine learning algorithms for personalized recom mendations, analyzing user behavior, search patterns, and enrollment trends to suggest relevant courses When a user selects a course for enrollment, the Process Enrollment module is activated. This module: 1. Validates the User Profile: Ensures the user has the necessary credentials or subscription access. 2. Updates Enrollment Records: Adds the course to the user's learning dash board. 3. Notifies the Course Provider: If the course is externally hosted, the system sends an API request for official enrollment. The business logic layer en- sures that both the User Database and Pro cessed Database are updated in real-time, reflecting accurate enrollment statuses.

III. DATA FLOW DIAGRAM

The data flow diagram (DFD) as shown in the fig 3.1 depicted illustrates the operational flow of an online course management system, which is designed to streamline the process of course data management, user interaction, and enrollment processing. The system begins with the interaction between Course Providers and the Fetch Courses Data process. Course Providers, being external entities, supply the initial course data, which is then collected and stored in the Course Database. This database serves as a central repository for all raw course information. Subse quently, the Organize And Index Courses process takes the raw data from the Course Database and structures it into a more accessible format. This organized data is then stored in the Processed Database, which is specifically designed to support efficient searching and rec-ommendation functionalities. The Search Recommend process utilizes the Processed Database to perform user queries and provide person alized course recommendations. This process is pivotal as it directly interacts with the User Database, which contains detailed user information, including their prefer ences and enrollment history. When a user decides to enroll

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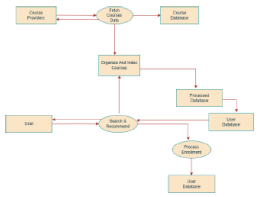

Fig. 2. Data Flow Diagram

in a course, the Process Enrollment process is triggered. This process updates both the Processed Database and the User Database to reflect the new enrollment status. The User Database is crucial for maintaining an accurate record of user enrollments and preferences, which can further refine the recommendation engine over time. Throughout this system, data flows in a structured manner, ensuring that course infor- mation is accurately captured, organized, and made available to users in a user-friendly manner. The DFD highlights the interconnectivity between various components of the system, emphasizing the importance of each process in delivering a seamless online learning experience. This systematic approach not only enhances the user experience but also ensures that the system is scalable and maintainable, which is essential for the growth and success of any online course platform

IV. IMPLEMENTATION DETAILS

The Online Course Aggregator System is meticulously designed to aggregate, process, and present a vast array of courses to users efficiently. This system leverages a Data Flow Diagram (DFD) to visualize the movement and transforma- tion of data from its initial collection from multiple course providers to its final presentation to users. The architecture is structured into multiple interconnected layers, each responsible for a specific function, ensuring modularity, scalability, and performance optimization The data management layer is at the core of the system, facilitating efficient storage, retrieval, and processing of course-related information. The data flow be gins with the Fetch Courses Data process, responsible for gathering raw course information from various online plat- forms, including universities, MOOCs (Massive Open Online Courses), and third-party education providers. The system utilizes web scraping, APIs, and direct database integrations to extract structured course details such as course name, provider, duration, syllabus, pricing, and in structor information. Once retrieved, this data is stored in the Course Database, which serves as the foundational repository. This database follows a relational schema to ensure data integrity, enabling effi- cient storage and retrieval operations. The Course Database maintains the following key entities: • Courses Table: Stores essential details of courses such as ID, title, provider, duration, and cost. • Providers Table: Holds information about various course providers, includ ing their names, API endpoints, and data update frequency. • Categories Table: Organizes courses into predefined categories such as Tech nology, Business, Science, and Arts.

Thedevelopment of the Online Course Aggregator follows a structured method ology comprising several key phases, in- cluding planning, development, testing, and deployment. Each phase ensures the systematic execution of the project, fSystem Design and Development • System Design and Development: Course Data Collection and Integra tion The first step in developing the platform involves collecting course data from multiple online learning platforms. This is achieved through web scrap ing, API integration, and database management techniques to ensure real-time updates on course availability, pricing, and reviews. The system is designed to standardize data from different sources for seamless aggregation and com parison. • Recommendation Algorithm Development: A key feature of the aggre gator is its intelligent recommendation system, which utilizes machine learning algorithms to provide personalized course suggestions. The algorithm consid ers user preferences, past learning behavior, course ratings, and trending topics to enhance course discovery and engagement. • User Interface (UI) and Experience (UX) Design:The frontend of the application is designed with a user-friendly interface to ensure easy navigation, efficient search, and intuitive course comparison. Technologies such as React.js or Vue.js may be used to develop a responsive design that works across different devices. • Performance Testing and Deployment: Before de- ployment, rigorous test ing is conducted to ensure the platform functions optimally. This includes unit testing for individual components, integration testing for API functionality, and load testing to assess system performance under high traffic. Once testing is completed, the application is deployed on a cloud- based server to ensure scalability and accessibility for users worldwide

V. RELATED WORK

Survey 1: Web Scraping and Query Answering Malik and Rizvi, in their 2011 study presented at the International Conference on Computational Intelligence and Com munica- tion Networks in Gwalior, India, highlighted the benefits of web scraping and query answering, such as automated data collection, structured data extraction, and enhanced efficiency in handling large datasets. Their research explored the in- tegra tion of web usage mining with semantic notation to improve data retrieval accuracy. Singrodia, Mitra, and Paul, in their 2019 research at the International Conference on Computer Communication and Informatics in Coimbatore, India, emphasized the role of web scraping in enabling real- time information retrieval, which is critical for f ields such as business intelligence, healthcare analytics, and financial forecasting. They also discussed the growing importance of AI-driven scraping tools that opti mize data extraction and minimize human intervention. Bale and colleagues, in their 2022 study at the International Conference on Electronics and Sustainable Commu nication Systems, explored AI-powered scraping techniques, which have improved accuracy in text and image-based data extraction. Their research emphasized that automated data integration from multiple sources en- hances analytical capabilities but also introduces challenges

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such as data redundancy and inconsistency, which require sophisticated cleaning techniques [1] . Survey 2: Web Scrap- ing for Criminal and Missing Children Identification Ayyap pan and Matilda, in their 2020 study at the International Conference on System, Computation, Automation, and Net- working in Pondicherry, discussed the applica tion of web scraping for identifying criminals and missing children using facial recog nition technology. They highlighted tools such as the Haar Cascade Classifier and web scraping libraries like BeautifulSoup, Scrapy, and Selenium, which enhance fea ture extraction accuracy. Their research demonstrated that real- time data collection from government and law enforcement websites significantly improves identification rates. However, they emphasized concerns related to privacy risks, the reliance on high-quality images for effective recognition, and the legal challenges associated with automated data collection. They also noted that ethical considerations, such as con sent for using publicly available images, must be addressed to prevent misuse of the technology [2]. Survey 3: Web Crawling and Scraping Techniques Mishra and Pujari, in their 2011 study at the 2nd International Conference on Computer and Com- munication Technology in Allahabad, reviewed various web crawling and scraping methodolo gies, including breadth-first and depth-first crawling, as well as modern frameworks such as BeautifulSoup, Scrapy, and Puppeteer. Their study identified key advan tages of web crawling, such as large-scale data retrieval for big data applications and automated indexing for search engines. They examined the role of automated data ag- gregation in industries such as e-commerce, financial analytics, and social media monitoring while addressing challenges like legal implications, high computational costs, and the frequent need for scraper maintenance due to changes in website structures. The research also explored the importance of ethical scraping practices, stressing compliance with website terms of service and legal frameworks like GDPR [3]. Survey 4: Twitter Scraping for Profiling Education Staff Herlawati, Handayanto, Ekawati, Meutia, Asian, and Aditiawarman, in their 2020 study at the Fifth Inter national Conference on Informatics and Com- puting in Gorontalo, Indonesia, inves tigated the use of Twitter scraping to profile education staff. They employed tools such as Twecoll and Gephi to analyze educational discussions and content-sharing patterns. Their findings demonstrated the use- fulness of social media data in trend analysis and knowledge- sharing behavior among educators. However, they high lighted limitations such as cross-platform data gaps, ethical concerns surrounding user privacy, and potential biases from analyzing a single social media platform. The study suggested that inte-grating data from LinkedIn and Google Scholar could pro vide a more comprehensive view of an educator's online presence. Additionally, they discussed the role of AI-driven sentiment analysis to assess educators' engagement levels and the impact of their online interactions [4]. Survey 5: Web Scraping in Data Science Applications Valova, Mladenova, Kanev, and Halacheva, in their 2023 research at the 31st National Conference with Inter national Participation (TELECOM) in Sofia, Bulgaria, examined the role of web scraping in data science, focusing on its use in data collection, preprocessing, and analysis. They discussed various scraping tools such as BeautifulSoup and Scrapy and explored key challenges like legal restrictions, ethical concerns, and handling dynamic web structures that frequently change, making automation difficult. Their research emphasized the role of machine learning in automating data cleaning and pattern recognition, enabling organizations to extract meaningful insights from un structured web data. They also highlighted that web scraping is essential for pre dictive analytics, helping businesses forecast trends and consumer behavior by ana lyzing large datasets from multiple sources [5]. Survey 6: Automated Web Scraping for Business Intelligence Chennupati, Pra has, Ghali, and Venugopalan, in their 2024 study at the IEEE 9th International Conference for Convergence in Technology in Pune, analyzed the application of automated web scraping in business intelligence. They reviewed different scrap ing methodologies and their effec- tiveness in gathering structured data for informed decision- making. Their research identified risks such as violating web- site terms of service, encountering anti-scraping mechanisms, and managing large volumes of unstructured data that require extensive preprocessing. They also discussed the impact of web scraping on economic intelligence, allowing businesses to forecast de mand and optimize pricing strategies.

VI. EXPERIMENTAL RESULTS

T The Login and Signup pages of the Online Course Aggregator provide a secure and user-friendly authentication system, enabling users to create accounts and access per-sonalized features. The pages are built using React.js for a seamless frontend experience, while the Flask backend handles authentication logic. The signup page allows new users to register by providing their name, email, and password, which are securely stored in a PostgreSQL database after encryption. The login page enables existing users to sign in using their registered credentials, with authentication managed via JWT tokens for secure session handling. Proper vali dation is implemented to prevent invalid inputs, and error messages guide users in case of incorrect login attempts. Once authenticated, users can access personalized features like bookmarking courses and receiving recommendations. The system en sures security through password hashing and token-based authentication, preventing unauthorized access and maintaining user data privacy The registration process in the Online Course Aggregator allows users to create an account securely and access personalized features. When a new user visits the Signup Page, they are required to enter details such as name, email, and password. The frontend, built with React.js, performs basic input validation to ensure correct data entry. Once submitted, the data is sent to the Flask backend, where the system verifies the email's uniqueness by checking the PostgreSQL database. The password is securely hashed using bcrypt before being stored in the database to enhance security. Upon successful registration, the backend generates a JWT (JSON Web Token) and sends it to the frontend, allowing the user to stay logged in. The user is then

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redirected to the dashboard, where they can search for courses, apply f ilters, and bookmark preferred courses. This process ensures a secure and efficient user onboarding experience, pre- venting unauthorized access while maintaining data integrity The Search Page in the Online Course Aggregator allows users to quickly find relevant courses based on their interests. Built using React.js, it provides a user friendly interface where users can enter keywords related to the course they are looking for. To enhance the search experience, the page includes advanced filtering options, enabling users to refine their search based on course provider (e.g., Udemy, Coursera, edX), price (free/paid), duration (short/long courses), rating, and skill level (beginner, intermediate, advanced). Once the user enters a query and ap plies filters, the request is sent to the Flask back- end, which processes the data and retrieves matching results from the PostgreSQL database. The Result Page displays the search results in a structured format, showing key details such as course title, provider, rating, price, duration, and a direct link to the course. Users can sort the results based on criteria like best-rated, most relevant, or lowest price. Additionally, authenticated users can bookmark courses for future reference. If no results are found, the page provides suggestions for similar courses based on the query. The seamless interaction between the search and result pages ensures a smooth and efficient user experience, helping learners find the best courses tailored to their needs.

VII. FUTURE WORK

While the current prototype provides a functional course aggregation experience, several enhancements are planned:

Real-time API Integration: Incorporate official APIs from platforms like Coursera and Udemy to retrieve up-to-date course data.

User Accounts & Personalization: Enable users to create profiles, save favorites, and receive tailored recommendations based on browsing history.

Advanced Filtering and Sorting: Add filters by price, dura- tion, difficulty level, and platform to refine search results.

Database Migration: Transition from static datasets to robust databases (e.g., MongoDB, PostgreSQL) for scalability and concurrency support.

AI-Driven Recommendations: Employ machine learning techniques to suggest courses aligning with user preferences and skill levels.

Mobile App Development: Extend platform reach by build- ing native or cross-platform mobile applications.

These improvements will help make the aggregator more competitive and valuable to learners.

VIII. CONCLUSION

The development of an online course aggregator presents a transformative so lution for learners seeking streamlined access to diverse educational content across multiple plat- forms. By centralizing courses from various providers, the system en hances accessibility, simplifies course discovery, and aids users in making informed decisions based on factors like course ratings, instructor credibility, and pricing. The implementation of advanced web scraping, API integrations, and intelligent recom mendation algorithms ensures that users receive personalized suggestions tailored to their learning preferences The development of an online course aggregator presents a transformative so lution for learners seeking stream- lined access to diverse educational content across multiple platforms. By centralizing courses from various providers, the system en hances accessibility, simplifies course discovery, and aids users in making informed decisions based on factors like course ratings, instructor credibility, and pricing. The implementation of advanced web scraping, API integrations, and intelligent recom mendation algorithms ensures that users receive personalized suggestions tailored to their learning preferences

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Local Workers Hiring Portal

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Abstract—The Local Workers Hiring Portal is a mobile-based platform designed to bridge the gap between users seeking skilled workers and workers looking for job opportunities. The system facilitates seamless interaction by allowing users to search for workers such as plumbers, painters, and electricians, and send job requests based on their requirements. Upon receiving a request, workers get notified and can either accept or reject the job. The platform includes a user-friendly registration and authentication system with OTP-based login, ensuring secure access for both users and workers. The backend is developed using Node.js with Express.js, and MongoDB is used as the database to store user and worker information, job listings, and requests. The frontend is built using Android Kotlin, providing an intuitive interface for users and workers. An admin panel is integrated to manage user and worker data, monitor job requests, and generate reports for better insights. The system also features a rating and review mechanism, allowing users to provide feedback after job completion, ensuring reliability and trust within the platform. This project aims to digitize and simplify the process of hiring skilled workers while ensuring transparency, efficiency, and ease of use. By eliminating intermediaries and enabling direct user-worker interaction, the platform enhances the accessibility of local labor services, ultimately benefiting both service providers and seekers.

I. INTRODUCTION

In today's fast-paced world, finding skilled local workers for household or small business tasks can be challenging. Many people struggle to locate reliable professionals such as plumbers, painters, electricians, and carpenters. Traditional methods of hiring workers through word-of-mouth or classifieds are often inefficient and time-consuming. To address this issue, we present the Local Workers Hiring Portal, a mobilebased application designed to connect users with skilled workers in their area. This platform enables users to search for workers, view their profiles, and send job requests. Workers receive notifications for job requests and can either accept or reject them based on their availability. The portal also incorporates a secure OTP based authentication system to ensure verified access for both users and workers. Additionally, a rating and review system allows users to provide feedback on workers' performance, enhancing trust and reliability within the platform The backend is developed using Node.js with Express.js, ensuring a scalable and efficient server-side architecture, while MongoDB is used to manage user and jobrelated data. The frontend, built with Android Kotlin, provides a seamless and user-friendly experience. An admin panel is also included for monitoring user activ ities, managing job listings, and generating reports to improve platform efficiency. The Local Workers Hiring Portal aims to streamline the process of hiring local workers, improve accessibility to skilled professionals, and provide a hassle free experience for users. By leveraging modern technology, the platform ensures a more organized and efficient way of connecting service seekers with service providers, fostering economic growth and job opportunities in local communities.

II. MOTIVATION

In today's fast-paced world, finding reliable and skilled workers for household or personal tasks like plumbing, cooking, and painting remains a challenge. Many individuals struggle to connect with trustworthy service providers, leading to de lays and inefficiencies in completing essential work. Traditional methods, such as word-of-mouth recommendations or manual searches, are time-consuming and often unreliable. To address this gap, the Local Workers Hiring Portal aims to create an efficient, secure, and user-friendly platform where users can easily find and hire skilled workers based on their requirements. By integrating phone number authentication, real time request management, and a rating system, the platform ensures credibility and transparency. Additionally, workers can showcase their skills and expand their opportunities, contributing to local employment growth. By leveraging modern technology, the platform streamlines the hiring process, making it more accessible, efficient, and secure for both users and workers.

III. OBJECTIVES

The primary objective of this project is to develop a reliable and efficient Local Workers Hiring Portal that connects users with skilled workers for various tasks such as plumbing, painting, and cooking. The system aims to streamline the worker hiring process by providing a secure, user-friendly platform where users can easily search for workers, send job requests, and receive services without unnecessary delays. By incorporating phone number authentication with OTP verification, the platform ensures secure user access and

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prevents fraudulent activities. Workers can showcase their skills by uploading details of their previous work, enabling users to make informed hiring decisions. Key Objectives: 1. Secure phone number authentication with OTP verification ensures only genuine users and workers can access the platform, preventing unauthorized ac cess. 2. Users can search for workers by category, such as plumbers, painters, or electricians, and send job requests directly through the platform. 3. An advanced search feature enables users to filter workers based on skills, location, availability, and user ratings for better matchmaking. 4. Workers can create detailed profiles where they list their skills, availability, and upload images of past work to showcase their experience 5. The platform allows users to register as both service seekers and workers, enabling flexibility for those who wish to offer services as well as hire others 6. Users can rate workers, leave reviews, and provide feedback, helping others make informed hiring decisions based on service quality. This system ensures a seamless experience for both workers and users while fostering trust, efficiency, and economic opportunities in local communities.

IV. LITERATURE SURVEY

J. Smith and A. Brown (2022)[1] explored how online job matching systems leverage Machine Learning (ML) and Natural Language Processing (NLP) to automate job recommendations. These technologies help match job seekers with relevant job postings by analyzing keywords, skills, and job descriptions, reducing the manual effort required for job searching. NLP enhances user interaction by enabling intelligent search functionalities, ensuring job seekers and employers find the most relevant results quickly. The automation of job matching significantly improves efficiency, reducing the time required for users to find suitable employment opportunities. How ever, AI-based job recommendation systems require large datasets to train machine learning models effectively, which can introduce biases if the data is not diverse or representative. Additionally, security concerns related to data privacy and the need for robust authentication mechanisms are crucial considerations for ensuring user safety. Despite these challenges, AIpowered job matching platforms continue to improve, offering better accuracy, automation, and a streamlined hiring process. L. Gonzalez (2021)[2] examined the role of mobile-based hiring platforms in connecting job seekers with employers using modern technologies such as Flutter, React Native, Firebase, and Geolocation APIs. These platforms provide realtime access to job listings, allowing users to engage with potential employers instantly. Mobile hiring solutions improve accessibility and convenience, enabling workers to receive job notifications and respond to job postings anytime, anywhere. The integration of Geolocation APIs ensures that users can find job opportunities in their immediate vicinity, increasing the likelihood of quick and efficient hiring. However, mobile applications often face performance challenges such as high battery consumption due to continuous location tracking and the need for frequent updates to maintain security and functionality. Furthermore, data privacy concerns arise due to the col lection of location-based information, requiring strong encryption and user consent mechanisms. Mobile-based hiring platforms have revolutionized the job market by making job searches more accessible, faster, and location-specific M. Johnson (2020)[3] discussed the significance of ratings and reviews in online hiring platforms and their impact on trust and decision-making. These platforms utilize Sentiment Analysis, Review Filtering Algorithms, and Weighted Feedback Systems to ensure that users receive reliable and accurate reviews. Ratings provide transparency, allowing employers to assess a worker's past performance based on feedback from previous clients. Additionally, review filtering algorithms help eliminate spam and fake reviews, ensuring authenticity. However, ratings and reviews are susceptible to manipulation, as some users may attempt to artificially inflate their ratings or post misleading reviews to harm competitors. To address these challenges, advanced verification mechanisms such as AI-driven fraud detection and identity confirmation are used. Despite the potential for manipulation, ratings and reviews remain essential for ensuring credibility, improving user confidence, and fostering a trustworthy online hiring ecosystem. R. Patel and D. Wang (2019)[4] emphasized the importance of security and authentication in web-based job portals, particularly in protecting user data and preventing unauthorized access. They explored the use of JWT (JSON Web Token), OAuth 2.0, and Multi-Factor Authentication (MFA) to enhance security in hiring platforms. JWT ensures secure user authentication by encrypting session tokens, preventing identity theft and session hijacking. OAuth 2.0 enables secure third party authentication, allowing users to log in using existing social media or email credentials. MFA further enhances security by requiring users to verify their iden tity through multiple authentication steps such as OTP verification or biometric authentication. While these security measures effectively prevent hacking attempts and unauthorized access, they can also complicate the user experience by adding extra steps to the login process. Therefore, hiring platforms must balance security and usability, ensuring that users can easily access their accounts while maintaining strong protection against cyber threats. T. Nguyen and K. Lee (2023)[5] analyzed the benefits of cloud-based hiring sys tems, focusing on scalability and efficiency. These platforms utilize AWS, Google Cloud, Firebase, and MongoDB Atlas for realtime data synchronization, high avail ability, and automated scaling. Cloud infrastructure allows hiring portals to handle large numbers of users simultaneously without performance degradation, making them ideal for growing job marketplaces. Load balancing techniques distribute user requests across multiple servers, preventing overload and ensuring smooth system performance. However, cloud-based systems face challenges related to operational costs, data security, and dependence on third-party service providers. Unauthorized access and cyber threats are major concerns, requiring strong encryption and access control mechanisms. Despite these challenges, cloud-based hiring platforms enable efficient, scalable, and cost-effective job matching solutions, ensuring seamless user experiences and improved system reliability. H. Kim and P. Roberts (2024)[6] explored the role of

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AI-based skill matching in employment portals, emphasizing the use of Natural Language Processing (NLP) and Machine Learning (ML) for efficient candidate-job matching. Resume parsing technology extracts relevant information from resumes, matching skills with job descriptions and ranking candidates accordingly. This automated process significantly reduces hiring time and minimizes the need for manual resume screening. However, the accuracy of AI-based skill matching depends on the quality and diversity of training data. Bias in datasets can lead to inaccurate job recommendations, while outdated information may result in mismatched candidates. To improve accuracy, AI systems continuously refine their algorithms, incorporate human oversight, and validate data sources. AI-driven skill matching has significantly improved the hiring process by enhancing efficiency, reducing hiring time, and increasing the accuracy of job-worker pairings. S. M. Vadivel and R. Sunny (2023)[7] analyzed the effectiveness of online job portals in HR recruitment using the Analytic Hierarchy Process (AHP), a structured decision-making framework. AHP assigns scores to candidates based on multiple weighted factors such as skills, experience, and ratings, allowing recruiters to make informed hiring decisions. This method ensures objectivity and minimizes bias in candidate selection. However, AHP requires predefined weight age parameters, which may not be flexible enough to adapt to real-time hiring needs. Additionally, the complexity of AHP makes it challenging to implement in dynamic job marketplaces where hiring criteria may change frequently. To address these limitations, some hiring platforms combine AHP with AI-based ranking algorithms to balance structured decision-making with adaptability. AHP-based evaluation systems enhance recruitment accuracy, streamline candidate assessment, and ensure a systematic approach to hiring. S. M. Vadivel and R. Sunny (2023)[8] examined the impact of mobile applications for finding skilled workers, focusing on the use of Firebase, MongoDB, and realtime authentication systems to enhance worker discovery and security. Mobile hiring applications provide users with instant access to skilled workers, allowing them to post jobs, browse worker profiles, and communicate seamlessly. The use of realtime databases ensures that job listings and worker availability are updated instantly, improving efficiency. However, mobile hiring platforms face challenges such as scalability limitations, data privacy concerns, and the need for advanced filtering mechanisms. Ensuring fast response times, secure authentication, and reliable worker ratings is critical for maintaining user trust and platform credibility. Cloud integration and AI-driven recommendation systems can further enhance the performance of mobile hiring applications, making them more efficient, secure, and user-friendly.

V. DATA FLOW DIAGRAM

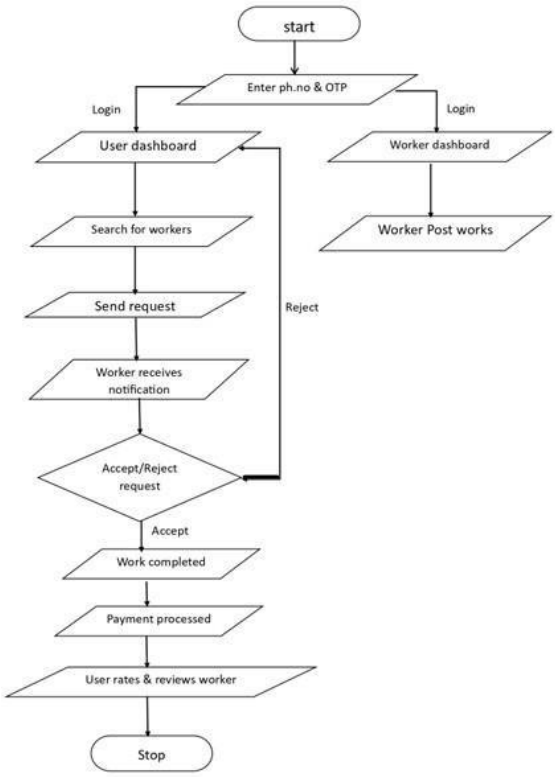

Fig. 1. Data Flow Diagram.

VI. SYSTEM ARCHITECTURE

The system architecture is depicted in the figure 3.1. The data flow diagram illustrates the flow of data and interactions between users, workers, the database, and various system components. EXPLANATION:The Local Worker Hiring Portal illustrates the structured process of connecting users with workers efficiently. The system begins with users and workers entering their phone numbers and verifying their identities through OTP authentication, ensuring security and preventing unauthorized access. Once logged in, users are directed to their dashboard, where they can search for workers based on specific services such as plumbing, electrical work, or painting.On the other hand, workers access their dashboard, allowing them to post details of their skills and past work, making them more discoverable to potential customers. Users can browse the platform and send service requests to workers of their choice. Upon sending a request, the worker receives a notification and has the option to either accept or reject it. If the request is rejected, the user can search for another worker. However, if accepted, the worker commits to performing the requested service. Once the job is completed, the system processes the payment, either through an integrated online gateway or in person, depending on the platform's implementation. After the

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service is successfully completed, users are encouraged to rate and review the worker, contributing to the credibility and quality assurance of the platform. Higher ratings and positive reviews help workers gain more visibility and increase their chances of securing future jobs, while negative feedback helps maintain service quality by alerting other users about potential issues. This structured workflow ensures a smooth, secure, and efficient experience for both users and workers, en abling a seamless interaction between service seekers and providers. The system is designed with key features such as secure authentication, real-time notifications, a job acceptance/rejection mechanism, seamless payment processing, and a feedback system that enhances trust and reliability.

VII. TECHNICAL DETAILS

The technical implementation of this project involves a combination of back end integration, and database management to create an efficient worker hiring sys tem.

A. Technology Stack The backend of the system is developed using Node.js and Express.js, ensuring a fast and scalable API-based architecture. MongoDB is used as the database due to its flexible schema, allowing efficient data storage and retrieval. The frontend is built using Android Kotlin, ensuring a dynamic and interactive user experience. For authentication, Firebase Authentication with OTP login is implemented.

B. System Architecture The system follows a client-servermodel, where the Android-based frontend interacts with the backend API hosted on a server. The backend handles user authentication, request management, payment processing, and worker interactions. Data is stored in MongoDB, ensuring smooth access and retrieval. The worker dashboard allows workers to manage their services and accept or reject job requests, while the user dashboard enables users to search for workers, send requests, and provide feedback after service completion.

C. Deployment and Accessibility The backend API isdeployed on a cloud server, ensuring high availability and scal ability. The mobile application is developed for Android devices and can be dis tributed through app stores. The system is designed to handle multiple user requests simultaneously, providing a smooth and efficient hiring experience

D. Rating and Review Mechanism After work completion,users can rate and review workers, helping future users make informed decisions. The review system stores ratings in the database and displays them on worker profiles to enhance
credibility

VIII. EXPERIMENTAL RESULTS

The Local Worker Hiring Portal evaluate the system's functionality, perfor mance, and user experience. The results analyze how efficiently users can search for workers, send requests, and receive responses. Key aspects such as system response time, accuracy in worker matching, and notification efficiency are tested. Addi tionally, user feedback helps assess ease of navigation and overall satisfaction. Any errors encountered during testing are documented and resolved to improve system reliability. The findings highlight the platform's effectiveness in connecting users with workers and ensuring smooth service execution

IX. USER AND WORKER LOGIN

The login page of the Local Worker Hiring Portal provides a seamless au thentication process for both users and workers. Users can log in or sign up using their phone number with OTP verification or sign in via Google. Once logged in, users gain access to their dashboard, where they can search for workers, send service requests, and manage ongoing tasks. On the other hand, workers also log in through the same interface and are directed to their dashboard, where they can post their skills, receive job requests, and respond accordingly. This intuitive login system ensures a smooth and secure entry into the platform for both parties.

Fig. 2. Login page.

X. USER DASHBOARD

The user dashboard provides an intuitive interface where users can search for workers, explore suggested service categories like plumbing and electrical work, and view the most booked services. It also allows users to select their location and access various features like job history, favorites, and notifications.

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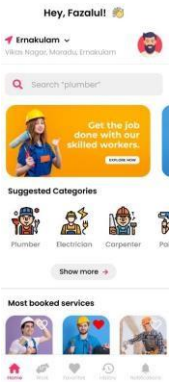

Fig. 3. user dashboard.

XI. WORKER CATEGORY

The worker category page displays various job roles, such as plumber, electrician, carpenter, painter, cook, and more. It helps users easily navigate and find the right type of worker for their needs. The search bar at the top allows users to quickly look up specific professions, making the hiring process more efficient.

Fig. 4. workers category.

XII. WORKERS CATEGORY

The worker listing page for plumbers, where users can search for specific workers by name. The list displays various professionals along with their job roles, ratings, locations, and daily charges. Users can browse and select a worker based on their needs and budget.

XIII. WORKERS PROFILE

The worker profile page provides detailed information about an individual worker, including their name, profession, location, ratings, and reviews from previous clients also worker post their previous works. It also displays the worker's daily rate, helping users make informed hiring decisions.

Fig. 5. workers category.

Fig. 6. workers category.

XIV. CONCLUSION AND FUTURE SCOPE

The Local Worker Hiring Portal effectively bridges the gap between users seeking services and skilled workers, providing a streamlined and transparent plat form for job matching. With features like OTP authentication, separate dashboards for users and workers, request management, notifications, payment processing, and a rating system, the platform ensures efficiency, reliability, and ease of use. By digitizing the process of hiring local workers, the system eliminates traditional in efficiencies, making it more convenient for users to find trusted professionals while enabling workers to gain more job opportunities and build their reputation. Looking ahead, the platform can be enhanced with AI-based worker recom mendations, in-app communication, GPS tracking, and automated dispute resolu tion to improve user experience. Multi-language support, subscription plans for workers, and integration with government employment schemes can further expand the platform's reach. Additionally, incorporating more service categories can trans form it into a comprehensive marketplace for various on-demand services. With continuous improvements, the portal has the potential to become a leading

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solution for local job hiring, benefiting both workers and users alike.

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Natural Language To SQL Converter

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***Abstract*—Web based platform has been developed to simplify SQL database interaction through natural language processing. Users input natural language queries, which the system converts into executable SQL code, broadening database accessibility. Built with Streamlit, the application features an intuitive web interface, enhancing user experience. A secure user management system, using SQLite for authentication and administration, is integrated, ensuring data integrity. This web application stream- lines SQL query generation, serving as both a practical tool and an educational resource for database languages. Aiming to democratize database access for users across various experience levels, the platform enhances productivity and usability by making complex database operations more approachable. Through its intuitive design and efficient processing, this application simplifies the process of working with structured data, promoting wider engagement with SQL databases. The integrated user management and streamlined query generation enable users to efficiently manage and interact with data, fostering a deeper understanding of SQL concepts and database operations.**

I. Introduction

The ”Normal Language to SQL Converter” is a web-based platform designed to seamlessly translate natural language inputs into structured SQL queries. This innovative system addresses the challenges faced by non-technical users when interacting with databases, as it eliminates the need to manually write complex SQL statements. The project leverages advanced generative AI models integrated with Streamlit to create an intuitive and user-friendly platform. The core functionality of the application relies on powerful natural language processing (NLP) algorithms, which interpret user inputs and accurately generate corresponding SQL commands. The AI model employed in this project is trained to understand diverse linguistic patterns and map them to SQL syntax. This robust approach ensures high accuracy and flexibility, allowing the system to handle a wide range of SQL operations such as SELECT, JOIN, AGGREGATE functions, and nested queries. The application architecture is built on the Streamlit framework, which facilitates the development of interactive web applications. The interface is designed to be clean and accessible, allowing users to enter their queries with ease. Additionally, the system implements secure user authentication and role-based access control, ensuring that both regular users and administrators can operate within their defined privileges. The database interaction is managed through a dynamic query generation module that ensures optimal performance and minimizes errors. Furthermore, the integration with generative AI models enables real-time query generation, making the application efficient and responsive. The project’s modular design and scalability make it well-suited for various use cases, including data analysis, reporting, and business intelligence. By merging natural language processing with SQL generation, the ”Normal Language to SQL Converter” project represents a significant advancement in user-friendly data management solutions. This tool not only simplifies database operations but also empowers users with limited SQL expertise to leverage complex data querying techniques.

II. Motivation

In modern organizations, efficient data management and accessibility are essential for data-driven decision-making. However, many non-technical users struggle to write SQL queries, which limits their ability to retrieve and analyze data independently. This gap often leads to a reliance on database administrators or technical experts, causing delays and reducing productivity. Even users proficient in SQL may find creating complex queries involving joins, aggregations, or nested conditions to be a challenging and time consuming task. For example, a business analyst wanting to calculate total sales for the last quarter might not know how to write a query like SELECT SUM(sales) FROM sales data WHERE quarter = ’Q4’; Instead, they could simply ask, ”What were the total sales for the last quarter?” and the application would automatically generate the correct SQL statement. By leverag- ing advanced Natural Language Processing(NLP) techniques, the ”Normal Language to SQL Converter” project addresses these challenges by translating natural language inputs into accurate SQL statements. This approach not only reduces technical barriers but also empowers users to interact with databases efficiently, fostering a more productive and data- driven environment.

III. Objectives

”The Normal Language to SQL Converter” project aims to simplify database querying by developing a web-based application that enables users to interact with databases using plain English rather than complex SQL syntax. Utilizing

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advanced Natural Language Processing (NLP) techniques, the system accurately converts natural language inputs into SQL statements, reducing technical barriers and minimizing errors. The application enhances user accessibility through a user-friendly Streamlit interface, allowing non-technical users, such as business analysts, to retrieve data without SQL expertise. It also automates the generation of complex SQL queries, improving efficiency and accuracy. Additionally, role-based authentication ensures secure access for both regular users and administrators. By bridging the gap between human language and database queries, the project supports data-driven decision making and real-world applications.

- **Simplify Database Interaction:** Develop a web-based application that enables users to interact with databases using natural language rather than SQL syntax, making data querying more intuitive.
- **Leverage NLP Techniques for Text-to-SQL Conversion:** Utilize advanced Natural Language Processing (NLP) algorithms to accurately translate natural language inputs into structured SQL statements, effectively bridging the gap between human language and database queries.
- **Enhance User Accessibility:** Design the system to be accessible to non-technical users, minimizing the need for SQL knowledge and allowing anyone to interact with databases using plain English.
- **Reduce Technical Dependency:** Empower users, including business analysts and non-technical staff, to perform data retrieval independently, reducing reliance on database administrators and technical experts.
- **Increase Efficiency and Accuracy:** Automate the generation of SQL queries to minimize errors and reduce the time required for complex query formulation, even when dealing with joins, aggregations, or nested conditions.
- **Provide a User-Friendly Interface:** Develop the application using the Streamlit framework to create a clean, interactive, and user-centric interface that enhances usability and provides a smooth experience.

IV. Project Outline

The rest of the project report is organized as follows. In Chapter 1, the introduction provides an overview of the project, including motivation and objectives. Chapter 2 presents the literature survey, discussing existing research on natural language processing (NLP) and text-to-SQL conversion. Chapter 3 out lines the system design and methodol- ogy, including the use of NLP algorithms with AI-powered models and the web-based interface developed using Streamlit. Chapter 4 covers the implementation process, including model integration and back-end/front-end development. Chapter 5 discusses the expected results and analysis of the system's performance, focusing on accuracy, efficiency, and usability in converting natural language inputs to SQL. Finally, Chapter 6 concludes the project and suggests future improvements.

V. LITERATURE SURVEY

In their innovative work, Yulong Li, Kevin Chen-Chuan Chang, and Qifan Wang have developed SQLNet [1], a pioneering system designed to translate natural language queries into SQL statements. SQLNet leverages a neural architec- ture that eliminates the need for hand-crafted features, thus significantly enhancing the accuracy of SQL generation. By employing a sequence-to-set model, SQLNet addresses the challenge of generating SQL queries in a structured and coherent manner. The model incorporates a sketch-based decoding process to predict query structures before filling in specific values, thereby reducing errors commonly associated with conventional sequence-to-sequence models. This structured approach has proven effective in accurately parsing complex natural language inputs, making SQLNet a valuable tool for bridging the gap between human language and database queries. In a parallel study, Victor Zhong, Caiming Xiong, and Richard Socher introduced Seq2SQL [2], an end-to-end neural network designed to convert natural language questions into SQL queries. Unlike traditional methods that rely on manually designed templates, Seq2SQL uses reinforcement learning to generate more accurate and efficient SQL statements. The system incorporates an execution-guided decoding mechanism to compare the generated SQL with the actual database output, allowing it to refine the query through iterative learning. This approach has shown substantial improvements in query accuracy, especially when handling databases with complex schemas and numerous columns. Another significant contribution to this field is the work by Ilya Sutskever, Oriol Vinyals, and Quoc V. Le [3], who developed a sequence-to-sequence learning method using deep neural networks. This foundational technique has been instrumental in natural language processing applications, including natural language to SQL conversion. By using long short-term memory (LSTM) networks, the model effectively captures long-range dependencies, which is crucial for generating coherent and contextually accurate SQL statements from extended natural language inputs. Moreover, the development of the Spider dataset by Tao Yu et al. [4] marked a milestone in evaluating natural language to SQL models. As a large-scale complex dataset, Spider encompasses various database schemas and challenging SQL queries, fostering the advancement of models capable of generalizing across diverse database environments. The dataset has become a benchmark for assessing the performance of SQL generation models, highlighting the importance of schema encoding and contextual representation in achieving accurate SQL synthesis. In the context of conversational AI, the work by Antoine Bordes, Y-Lan Boureau,and Jason Weston [5] emphasizes the challenge of multi-turn dialogue understanding when generating SQL queries. Their study highlights that maintaining context and user intent across multiple conversational turns significantly impacts the accuracy of generated SQL. Integrating context-aware mechanisms into natural language to SQL models is crucial to achieving fluid and dynamic interactions, especially in chatbot-based data querying systems. The

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research by Jiacong He, Chao Zhang, and Honglak Lee [6] addresses the problem of generalizing SQL query generation to unseen databases. They proposed a schema-agnostic model that learns transferable representations, enabling it to adapt to new database schemas without additional fine-tuning. This approach is particularly valuable in scenarios where databases frequently change or are dynamically generated. In addition, the work by Wang et al. [7] on text-to-SQL generation using pre-trained language models like BERT and T5 demonstrated the effectiveness of leveraging large-scale language models for SQL query generation. By fine-tuning these models on text-to-SQL tasks, the researchers achieved state-of-the-art results, particularly in handling complex nested queries and ambiguous language inputs. Lastly, Paul Pu Liang et al. [8] explored multi-modal approaches to natural language to SQL conversion, combining textual and visual inputs to enhance query accuracy. This approach is particularly relevant in appli- cations where users interact with databases through graphical interfaces or dashboards, emphasizing the need for multi- modal fusion in next-generation query systems.

VI. Literature Review

SI No	Author	Title	Objective
1	Yulong Li, Kevin Chen-Chuan Chang, Qifan Wang	*SQLNet*	To develop a system that converts natural language queries into SQL using a neural architecture, eliminating manual feature engineering.
2	Victor Zhong, Caiming Xiong, Richard Socher	*Seq2SQL*	To convert natural language questions into SQL queries using reinforcement learning and an execution-guided decoding mechanism for enhanced accuracy.
3	Ilya Sutskever, Oriol Vinyals, Quoc V. Le	*Sequence-to-Sequence Learning [3]*	To introduce a method using LSTM deep neural networks for natural language processing, capturing long-range dependencies to generate SQL statements.
4	Tao Yu et al	*Spider Dataset*	To provide a large-scale complex dataset for evaluating natural language to SQL models, promoting advancements in schema encoding and contextual representation.
5	Antoine Bordes, Y-Lan Boureau, Jason Weston	*Multi-Turn Dialogue Understanding*	To address the challenge of maintaining context and user intent across multiple conversational turns when generating SQL queries.
6	Jiacong He, Chao Zhang, Honglak Lee	*Schema-Agnostic SQL Generation*	To develop a model that generalizes SQL query generation to unseen databases by learning transferable representations.
7	Wang et al	*Text-to-SQL Generation Using Pre-Trained Models*	To leverage large-scale pre-trained language models (like BERT and T5) for accurate SQL query generation, especially for complex queries.
8	Paul Pu Liang et al	*Multi-Modal SQL Generation*	To enhance SQL query accuracy by combining textual and visual inputs, particularly in graphical interfaces or dashboards.

TABLE I: Literature Sources

VII. Background Study

The ability to convert natural language queries into SQL statements is a trans formative innovation in data management and analysis. As businesses increasingly rely on large-scale data, the challenge lies in enabling non-technical users to efficiently interact with databases. SQL, being a structured query language, requires technical expertise to write accurate and optimized queries, while most users are more comfortable with natural language than SQL syntax. To bridge this gap, the concept of a Normal Language to SQL converter emerges as a practical solution. This project leverages Natural Language Processing (NLP) techniques and AI models to interpret user queries and generate corresponding SQL statements. Integrating these techniques into a Streamlit-based web application provides an intuitive interface where users can input natural language queries and receive accurate SQL translations. The core of this project involves advanced NLP algorithms to parse, understand, and map natural language queries into SQL syntax. The system analyzes the input query structure, iden- tifies keywords and contextual relationships, and maps them to SQL components like SELECT, WHERE, and JOIN. This approach ensures that the generated SQL accurately reflects the user's intent while minimizing errors. Using Streamlit as a web application framework ensures the solution is user and accessible via any browser, making it suitable for non-technical professionals. This interactive interface allows users to input natural language queries and instantly view the generated SQL output. By combining NLP, AI, and an interactive interface, the Normal Language to SQL converter aims to democratize data interaction, enabling users to query databases efficiently without requiring in-depth SQL knowledge. This approach not only improves accessibility but also significantly reduces the learning curve associated with traditional data querying methods.

VIII. Proposed System

A. Problem Statement

Retrieving data from databases can be a challenging task for non-technical users who lack proficiency in SQL. This limitation creates a dependency on technical experts to formulate complex SQL queries, leading to delays and inefficiencies in data access. In many scenarios, professionals from diverse domains need quick and accurate data retrieval for analysis and decision-making. The existing gap between natural lan- guage and SQL makes it difficult for users to interact with databases directly. Therefore, there is a need for a system that can seamlessly translate natural language inputs into SQL queries, enabling efficient data retrieval without requiring SQL expertise.

B. Proposed System Outline

The proposed system consists of two main components: the User Interaction Layer and the Text-to-SQL Conversion Layer. The User Interaction Layer offers a streamlined, user-friendly interface using Streamlit, allowing users to input natural language queries and view the generated SQL output. It also features secure user authentication with role-based access for admins and regular users. The Text to-SQL Conversion Layer leverages AI to translate natural language queries into structured SQL statements, handling complex query structures with high accuracy. Additionally, it integrates with SQLite

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for user data management and SQL query execution, ensuring efficient and scalable operations.

C. System Architecture

This AI-powered web tool converts natural language into SQL queries, ensuring secure login, role-based access, and seamless database interaction. The system architecture consists of multiple interconnected modules ensuring seamless conversion of natural language queries into SQL queries. The user inter-acts with the system via a web browser, accessing the Streamlit-based user interface. Through this interface, users can register, log in, and input natural language queries.User authentication and authorization are managed using SQLite, which securely stores user credentials and access permissions. Once authenticated, users can input natural language queries, which are processed by the natural language processing (NLP) module. This AI-powered module interprets user input and forwards it to the SQL generation module. The SQL generation module converts the processed query into a structured SQL command, using an API key stored in environment variables for secure access. The generated SQL query is then executed using the SQLite execution engine, retrieving the required data. For administrators, the system includes a dedicated admin panel built with Streamlit, providing access to user data stored in the SQLite database. Admins can manage user accounts and monitor query history. The system ensures security through role-based access control, environment variables for API security, and password encryption. The architecture maintains efficiency, accuracy, and scalability, making it a robust natural language-to-SQL solution.

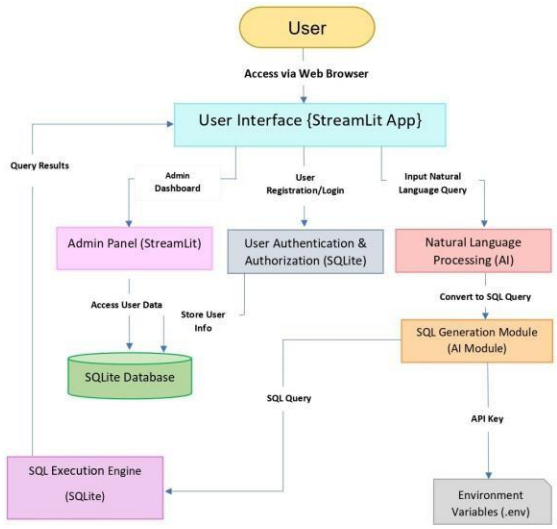

Fig. 1: System Architecture of the Natural Language to SQL Converter

D. Technical Details

The ”Natural Language to SQL Converter” web platform enables users to generate SQL queries from plain English inputs effortlessly. Leveraging AI, it translates natural language queries into accurate SQL code, making database interaction accessible to non-technical users. The system features a user-friendly interface built with Streamlit, allowing seamless input and query generation. The back-end, implemented in Python, integrates with SQLite for user management and query history. Additionally, an admin module provides access control and monitoring. By simplifying SQL query creation, SQL Converter empowers users to efficiently retrieve and manipulate data without requiring SQL expertise. Application Framework :The SQL converter is built on the Streamlit framework, chosen for its simplicity in developing interactive web applications. Streamlit’s Python-based structure allows for rapid prototyping and deployment. The framework also integrates seamlessly with various Python libraries and APIs, making it ideal for building a dynamic and user-friendly interface. AI Model Integration : The application leverages AI for natural language processing and SQL query generation. The model is accessed via API calls, where user input is processed and transformed into structured SQL syntax. By using the latest version of AI model textToSql, the system en- sures high accuracy and performance. User Authentication and Role Management : User authentication is implemented using SQLite, a lightweight relational database system. The application features role-based access control, distinguishing between regular users and administrators. Authentication processes include login, registration, and secure password management. Admin users have additional privileges to view query histories and manage user accounts. Front-End Design : The front-end of the application is designed using Streamlit, focusing on a clean and intuitive user experience. Features include a text input area for natural language queries, a button to generate SQL code, and a dashboard displaying results. Back-End and Database Management : The back-end is developed in Python, utilizing the Streamlit framework for handling user interactions and displaying results. The application connects to SQLite to manage user credentials, store generated SQL queries, and log user interactions. Error handling mechanisms ensure that any issues during query generation are promptly communicated to the user. Security Measures : To safeguard user data, password hashing techniques are applied before storing credentials in the database. The application follows best practices for data security, including input validation and secure session management. Implementation : After implementing security measures, the project integrates all components into a fully functional application. The AI-powered Text-to-SQL converter is deployed within Streamlit, ensuring efficient query processing. The backend, including API communication for SQL generation, is linked with SQLite for data management. The authentication system is tested for secure login, registration, and role-based access. The front end is refined for usability, featuring an interactive dashboard and input fields. Extensive

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testing ensures query accuracy, error handling, and security compliance. Finally, the project is deployed on a server, with future enhancements planned for scalability and improved AI model performance.

IX. METHODOLOGY

The development of the Natural Language to SQL Converter application was carried out through a structured and systematic approach, ensuring efficiency, accuracy, and scalability. The methodology consisted of multiple stages, including requirement analysis, design, implementation, testing, and deployment. The first phase involves identifying and analyzing the specific needs of a project management system. This includes gathering requirements from stakeholders to understand functionalities like task management, team collaboration, progress tracking, and reporting. A feasibility study is conducted to assess the technical and economic viability of the system. The goal is to develop a user-friendly application that streamlines project management processes while providing real-time updates and data analytics.

A. Requirement Analysis and Design

- **Problem Definition and Feasibility Study:** The first phase involves identifying and analyzing the specific needs of a project management system. This includes gathering requirements from stakeholders to understand functionalities like task management, team collaboration, progress tracking, and reporting. A feasibility study is conducted to assess the technical and economic viability of the system. The goal is to develop a user-friendly application that streamlines project management processes while providing real-time updates and data analytics.
- **System Design and Architecture:** The system architecture was carefully designed to ensure modularity and scalability. The application follows a three-tier architecture comprising the front-end (Streamlit-based UI), back-end (Python Flask/Streamlit for request handling), and database (SQLite for storing user credentials and queries). The core component involves integrating AI to process natural language queries and generate corresponding SQL queries. Additionally, an admin module was incorporated to manage user access and view query history.

B. Development and Integration

- **Front-End Development:** The front-end was developed using Streamlit, providing a user-friendly and interactive interface. The application includes login, registration, and query input modules, ensuring smooth user interaction. The dashboard is dynamically designed with role-based navigation, offering distinct views for users and administrators.
- **Back-End and API Integration:** The back-end logic was implemented using Python to handle requests and process user queries. AI API was integrated to process natural language inputs and generate SQL queries dynamically. A robust API handling mechanism was put in place to ensure seamless communication between the user interface and the AI model.

C. Database Management and Security

- **User Authentication and Role Management:** SQLite was used to store and manage user credentials, with role-based access control for both regular users and admins. The login and registration modules were secured using hashed passwords to ensure data protection. Admin privileges were granted selectively to manage the database effectively.
- **Data Storage and Query Logging:** The application maintains a query history for each user, allowing admins to monitor user activity and query patterns. All generated queries are logged in the database for future analysis and debugging, enhancing system reliability.

D. Testing and Implementation

The Testing and Implementation phases were essential for ensuring the functionality and reliability SQL Converter. Unit testing validated the accuracy of the AI model, user authentication, and database operations. Integration testing ensured smooth interaction between the front-end and back-end, including proper handling of user inputs, seamless database connectivity, and successful integration with the API. Finally, user testing was conducted to assess the application's usability, ensuring a smooth experience for non-technical users. Once testing was complete, the deployment phase ensured the application was securely launched, accessible, and performing optimally in the production environment.

X. EXPERIMENTAL RESULTS

To evaluate the performance and reliability of our system, experimentation was conducted using various test cases. This section presents the experimental results and analyses the effectiveness of the Natural Language to SQL Converter web in converting natural language queries to SQL statements accurately.

A. Introduction of the System

This is the homepage of an SQL Converter web application. It features a sidebar titled Admin Navigation with links to the Home, Registration Page, and Login Page. A warning message indicates that admin access is required to view user details. The main content welcomes users, explaining the tool's purpose, converting natural language queries into SQL. It highlights key features such as a user-friendly interface, efficiency, accuracy, flexibility, secure access, and scalability. The page encourages users to explore SQL learning and database management with AI-powered query generation. Admins must log in for additional functionalities like managing users.

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Fig. 2: Home Page

B. User Registration

The User Registration page of the SQL Converter web application facilitates new user account creation. The left sidebar navigation includes links to Home, Registration, and Login, with the active page visually distinguished. The main content area contains a form with input fields for Username, Email, and Password, utilizing HTML form elements and CSS styling for user-friendly interaction. A checkbox labeled Register as Admin enables role-based account designation. The password field includes an eye icon toggle for visibility control via JavaScript. The Register button triggers a POST request to the backend for account creation, while the Go to Login Page button navigates to the login screen.

Fig. 3: Registration Page

C. User Login

This login page, crafted with Streamlit, presents a clean interface for user authentication. The left sidebar offers navigation to the home and registration pages, while the main section features a ”User Login” heading with a lock icon, emphasizing security. Users input their username and password into designated fields, with password visibility toggled by an eye icon. The ”Login” button triggers credential verification against an SQLite database. Successful logins grant access to the application, potentially redirecting users to the main app interface. The ”Deploy” button in the top right corner suggests Streamlit’s deployment capabilities.

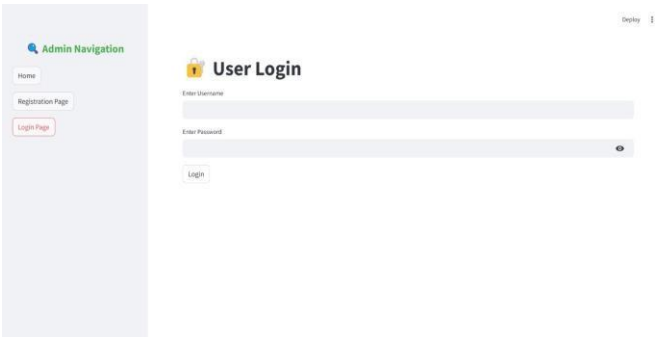

Fig. 4: Login Page

D. Generate SQL Query:Conversion Process

This part of the system’s main page is this, showcases a natural language to SQL conversion tool powered by AI Model. The user enters a plain English query, which is then sent to API. This AI, trained on extensive code and language data, interprets the user’s intent and translates it into a structured SQL query. The AI understands natural language constructs and maps them to corresponding SQL syntax and database operations. The generated SQL, representing the user’s re- quest, is then displayed back to the user in a readable format, along with explanations of the data types used in the query. This process bridges the gap between human language and machine-executable database commands.

Fig. 4: Interface

Fig. 5: example1

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E. Real-Time Query Processing and Error Handling

The application ensures efficient and real-time processing of user queries by leveraging asynchronous calls to the API. Once the SQL query is generated, the application validates the generated query to check for syntax errors and missing conditions.

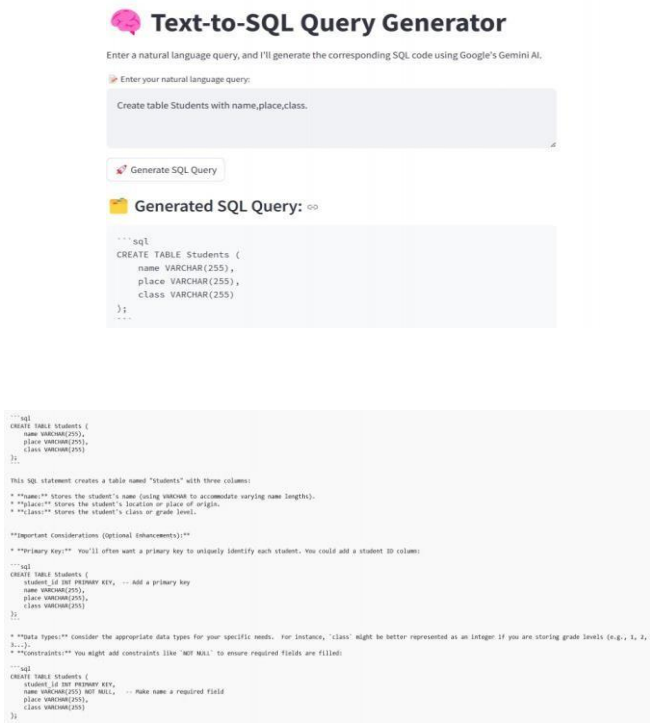

Fig. 6: example2

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CONCLUSION FUTURE SCOPE

This project demonstrates the viability of utilizing AI to translate natural language into SQL, simplifying database interaction through a web-based interface. The system's capacity to generate SQL from user input highlights the potential for accessible database operations, though accuracy is constrained by the lack of explicit schema incorporation. The project emphasizes the necessity of robust error handling and secu- rity protocols. This proof-of-concept serves as a foundation for developing intuitive, AI-driven database tools, aiming to democratize data access for a wider user base. Future development will focus on enhancing functionality and user experience. Integrating direct schema retrieval and query execution will ensure real-time data interaction and accuracy. Advanced query handling, including complex SQL and database-specific syntax, will expand applicability. User interface refinements, like query history and voice input, will improve usability. Robust security measures are crucial. Multi-database support, image and query scanning, and Excel table handling will broaden functionality. An API for external integration and AI model refinement on larger datasets will improve accuracy, leading to a comprehensive, AI-driven database platform.This project demonstrates the viability of utilizing AI to translate natural language into SQL, simplifying database interaction through a web-based interface. The system's capacity to generate SQL from user input highlights the potential for accessible database operations, though accuracy is constrained by the lack of explicit schema incorporation. The project emphasizes the necessity of robust error handling and security protocols. This proof-of-concept serves as a foundation for developing intuitive, AI-driven database tools, aiming to democratize data access for a wider user base. Future development will focus on enhancing functionality and user experience. Integrating direct schema retrieval and query execution will ensure real-time data interaction and accuracy. Advanced query handling, including complex SQL and database-specific syntax, will expand applicability. User interface refinements, like query history and voice input, will improve usability. Robust security measures are crucial. Multi-database support, image and query scanning, and Excel table handling will broaden functionality. An API for external integration and AI model refinement on larger datasets will improve accuracy, leading to a comprehensive, AI-driven database platform.

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Natural Language To SQL Converter

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***Abstract*—Web based platform has been developed to simplify SQL database interaction through natural language processing. Users input natural language queries, which the system converts into executable SQL code, broadening database accessibility. Built with Streamlit, the application features an intuitive web interface, enhancing user experience. A secure user management system, using SQLite for authentication and administration, is integrated, ensuring data integrity. This web application streamlines SQL query generation, serving as both a practical tool and an educational resource for database languages. Aiming to democratize database access for users across various experience levels, the platform enhances productivity and usability by making complex database operations more approachable. Through its intuitive design and efficient processing, this application simplifies the process of working with structured data, promoting wider engagement with SQL databases. The integrated user management and streamlined query generation enable users to efficiently manage and interact with data, fostering a deeper understanding of SQL concepts and database operations.**

I. Introduction

The ”Normal Language to SQL Converter” is a web-based platform designed to seamlessly translate natural language inputs into structured SQL queries. This innovative system addresses the challenges faced by non-technical users when interacting with databases, as it eliminates the need to manually write complex SQL statements. The project leverages advanced generative AI models integrated with Streamlit to create an intuitive and user-friendly platform. The core functionality of the application relies on powerful natural language processing (NLP) algorithms, which interpret user inputs and accurately generate corresponding SQL commands. The AI model employed in this project is trained to understand diverse linguistic patterns and map them to SQL syntax. This robust approach ensures high accuracy and flexibility, allowing the system to handle a wide range of SQL operations such as SELECT, JOIN, AGGREGATE functions, and nested queries. The application architecture is built on the Streamlit framework, which facilitates the development of interactive web applications. The interface is designed to be clean and accessible, allowing users to enter their queries with ease. Additionally, the system implements secure user authentication and role-based access control, ensuring that both regular users and administrators can operate within their defined privileges. The database interaction is managed through a dynamic query generation module that ensures optimal performance and minimizes errors. Furthermore, the integration with generative AI models enables real-time query generation, making the application efficient and responsive. The project’s modular design and scalability make it well-suited for various use cases, including data analysis, reporting, and business intelligence. By merging natural language processing with SQL generation, the ”Normal Language to SQL Converter” project represents a significant advancement in user-friendly data management solutions. This tool not only simplifies database operations but also empowers users with limited SQL expertise to leverage complex data querying techniques.

II. Motivation

In modern organizations, efficient data management and accessibility are essential for data-driven decision-making. However, many non-technical users struggle to write SQL queries, which limits their ability to retrieve and analyze data independently. This gap often leads to a reliance on database administrators or technical experts, causing delays and reducing productivity. Even users proficient in SQL may find creating complex queries involving joins, aggregations, or nested conditions to be a challenging and time consuming task. For example, a business analyst wanting to calculate total sales for the last quarter might not know how to write a query like SELECT SUM(sales) FROM sales data WHERE quarter = ’Q4’; Instead, they could simply ask, ”What were the total sales for the last quarter?” and the application would automatically generate the correct SQL statement. By leveraging advanced Natural Language Processing(NLP) techniques, the ”Normal Language to SQL Converter” project addresses these challenges by translating natural language inputs into accurate SQL statements. This approach not only reduces technical barriers but also empowers users to interact with databases efficiently, fostering a more productive and data-driven environment.

III. Objectives

”The Normal Language to SQL Converter” project aims to simplify database querying by developing a web-based application that enables users to interact with databases using plain English rather than complex SQL syntax. Utilizing

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advanced Natural Language Processing (NLP) techniques, the system accurately converts natural language inputs into SQL statements, reducing technical barriers and minimizing errors. The application enhances user accessibility through a user-friendly Streamlit interface, allowing non-technical users, such as business analysts, to retrieve data without SQL expertise. It also automates the generation of complex SQL queries, improving efficiency and accuracy. Additionally, role-based authentication ensures secure access for both regular users and administrators. By bridging the gap between human language and database queries, the project supports data-driven decision making and real-world applications.

- **Simplify Database Interaction:** Develop a web-based application that enables users to interact with databases using natural language rather than SQL syntax, making data querying more intuitive.
- **Leverage NLP Techniques for Text-to-SQL Conversion:** Utilize advanced Natural Language Processing (NLP) algorithms to accurately translate natural language inputs into structured SQL statements, effectively bridging the gap between human language and database queries.
- **Enhance User Accessibility:** Design the system to be accessible to non-technical users, minimizing the need for SQL knowledge and allowing anyone to interact with databases using plain English.
- **Reduce Technical Dependency:** Empower users, including business analysts and non-technical staff, to perform data retrieval independently, reducing reliance on database administrators and technical experts.
- **Increase Efficiency and Accuracy:** Automate the generation of SQL queries to minimize errors and reduce the time required for complex query formulation, even when dealing with joins, aggregations, or nested conditions.
- **Provide a User-Friendly Interface:** Develop the application using the Streamlit framework to create a clean, interactive, and user-centric interface that enhances usability and provides a smooth experience.

IV. Project Outline

The rest of the project report is organized as follows. In Chapter 1, the introduction provides an overview of the project, including motivation and objectives. Chapter 2 presents the literature survey, discussing existing research on natural language processing (NLP) and text-to-SQL conversion. Chapter 3 out lines the system design and methodology, including the use of NLP algorithms with AI-powered models and the web-based interface developed using Streamlit. Chapter 4 covers the implementation process, including model integration and back-end/front-end development. Chapter 5 discusses the expected results and analysis of the system's performance, focusing on accuracy, efficiency, and usability in converting natural language inputs to SQL. Finally, Chapter 6 concludes the project and suggests future improvements.

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V. LITERATURE SURVEY

In their innovative work, Yulong Li, Kevin Chen-Chuan Chang, and Qifan Wang have developed SQLNet [1], a pio- neering system designed to translate natural language queries into SQL statements. SQLNet leverages a neural architec- ture that eliminates the need for hand-crafted features, thus significantly enhancing the accuracy of SQL generation. By employing a sequence-to-set model, SQLNet addresses the challenge of generating SQL queries in a structured and coher- ent manner. The model incorporates a sketch-based decoding process to predict query structures before filling in specific values, thereby reducing errors commonly associated with conventional sequence-to-sequence models. This structured approach has proven effective in accurately parsing complex natural language inputs, making SQLNet a valuable tool for bridging the gap between human language and database queries. In a parallel study, Victor Zhong, Caiming Xiong, and Richard Socher introduced Seq2SQL [2], an end-to-end neural network designed to convert natural language questions into SQL queries. Unlike traditional methods that rely on manually designed templates, Seq2SQL uses reinforcement learning to generate more accurate and efficient SQL statements. The system incorporates an execution-guided decoding mechanism to compare the generated SQL with the actual database output, allowing it to refine the query through iterative learning. This approach has shown substantial improvements in query accuracy, especially when handling databases with complex schemas and numerous columns. Another significant contribu- tion to this field is the work by Ilya Sutskever, Oriol Vinyals, and Quoc V. Le [3], who developed a sequence-to-sequence learning method using deep neural networks. This foundational technique has been instrumental in natural language processing applications, including natural language to SQL conversion. By using long short-term memory (LSTM) networks, the model effectively captures long-range dependencies, which is crucial for generating coherent and contextually accurate SQL statements from extended natural language inputs. Moreover, the development of the Spider dataset by Tao Yu et al. [4] marked a milestone in evaluating natural language to SQL models. As a large-scale complex dataset, Spider encompasses various database schemas and challenging SQL queries, fos- tering the advancement of models capable of generalizing across diverse database environments. The dataset has become a benchmark for assessing the performance of SQL generation models, highlighting the importance of schema encoding and contextual representation in achieving accurate SQL synthesis. In the context of conversational AI, the work by Antoine Bordes, Y-Lan Boureau,and Jason Weston [5] emphasizes the challenge of multi-turn dialogue understanding when gener- ating SQL queries. Their study highlights that maintaining context and user intent across multiple conversational turns significantly impacts the accuracy of generated SQL. Inte- grating context-aware mechanisms into natural language to SQL models is crucial to achieving fluid and dynamic interac- tions, especially in chatbot-based data querying systems. The

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research by Jiacong He, Chao Zhang, and Honglak Lee [6] addresses the problem of generalizing SQL query generation to unseen databases. They proposed a schema-agnostic model that learns transferable representations, enabling it to adapt to new database schemas without additional fine-tuning. This approach is particularly valuable in scenarios where databases frequently change or are dynamically generated. In addition, the work by Wang et al. [7] on text-to-SQL generation using pre-trained language models like BERT and T5 demonstrated the effectiveness of leveraging large-scale language models for SQL query generation. By fine-tuning these models on text-to-SQL tasks, the researchers achieved state-of-the-art results, particularly in handling complex nested queries and ambiguous language inputs. Lastly, Paul Pu Liang et al. [8] explored multi-modal approaches to natural language to SQL conversion, combining textual and visual inputs to enhance query accuracy. This approach is particularly relevant in applications where users interact with databases through graphical interfaces or dashboards, emphasizing the need for multi-modal fusion in next-generation query systems.

VI. Literature Review

SI No	Author	Title	Objective
1	Yulong Li, Kevin Chen-Chuan Chang, Qifan Wang	*SQLNet*	To develop a system that converts natural language queries into SQL using a neural architecture, eliminating manual feature engineering.
2	Victor Zhong, Caiming Xiong, Richard Socher	*Seq2SQL*	To convert natural language questions into SQL queries using reinforcement learning and an execution-guided decoding mechanism for enhanced accuracy.
3	Ilya Sutskever, Oriol Vinyals, Quoc V. Le	*Sequence-to-Sequence Learning [3]*	To introduce a method using LSTM deep neural networks for natural language processing, capturing long-range dependencies to generate SQL statements.
4	Tao Yu et al	*Spider Dataset*	To provide a large-scale complex dataset for evaluating natural language to SQL models, promoting advancements in schema encoding and contextual representation.
5	Antoine Bordes, Y-Lan Boureau, Jason Weston	*Multi-Turn Dialogue Understanding*	To address the challenge of maintaining context and user intent across multiple conversational turns when generating SQL queries.
6	Jiacong He, Chao Zhang, Honglak Lee	*Schema-Agnostic SQL Generation*	To develop a model that generalizes SQL query generation to unseen databases by learning transferable representations.
7	Wang et al	*Text-to-SQL Generation Using Pre-Trained Models*	To leverage large-scale pre-trained language models (like BERT and T5) for accurate SQL query generation, especially for complex queries.
8	Paul Pu Liang et al	*Multi-Modal SQL Generation*	To enhance SQL query accuracy by combining textual and visual inputs, particularly in graphical interfaces or dashboards.

TABLE I: Literature Sources

VII. Background Study

The ability to convert natural language queries into SQL statements is a trans formative innovation in data management and analysis. As businesses increasingly rely on large-scale query language, requires technical expertise to write accurate and optimized queries, while most users are more comfortable with natural language than SQL syntax. To bridge this gap, the concept of a Normal Language to SQL converter emerges as a practical solution. This project leverages Natural Language Processing (NLP) techniques and AI models to interpret user queries and generate corresponding SQL statements. Integrating these techniques into a Streamlit-based web application provides an intuitive interface where users can input natural language queries and receive accurate SQL translations. The core of this project involves advanced NLP algorithms to parse, understand, and map natural language queries into SQL syntax. The system analyzes the input query structure, identifies keywords and contextual relationships, and maps them to SQL components like SELECT, WHERE, and JOIN. This approach ensures that the generated SQL accurately reflects the user's intent while minimizing errors. Using Streamlit as a web application framework ensures the solution is user and accessible via any browser, making it suitable for non-technical professionals. This interactive interface allows users to input natural language queries and instantly view the generated SQL output. By combining NLP, AI, and an interactive interface, the Normal Language to SQL converter aims to democratize data interaction, enabling users to query databases efficiently without requiring in-depth SQL knowledge. This approach not only improves accessibility but also significantly reduces the learning curve associated with traditional data querying methods.

data, the challenge lies in enabling non-technical users to efficiently interact with databases. SQL, being a structured

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VIII. Proposed System

A. Problem Statement

Retrieving data from databases can be a challenging task for non-technical users who lack proficiency in SQL. This limi- tation creates a dependency on technical experts to formulate complex SQL queries, leading to delays and inefficiencies in data access. In many scenarios, professionals from diverse domains need quick and accurate data retrieval for analysis and decision-making. The existing gap between natural lan- guage and SQL makes it difficult for users to interact with databases directly. Therefore, there is a need for a system that can seamlessly translate natural language inputs into SQL queries, enabling efficient data retrieval without requiring SQL expertise.

B. Proposed System Outline

The proposed system consists of two main components: the User Interaction Layer and the Text-to-SQL Conversion Layer. The User Interaction Layer offers a streamlined, user-friendly interface using Streamlit, allowing users to input natural language queries and view the generated SQL output. It also features secure user authentication with role-based access for admins and regular users. The Text to-SQL Conversion Layer leverages AI to translate natural language queries into structured SQL statements, handling complex query structures with high accuracy. Additionally, it integrates with SQLite

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for user data management and SQL query execution, ensuring efficient and scalable operations.

C. System Architecture

This AI-powered web tool converts natural language into SQL queries, ensuring secure login, role-based access, and seamless database interaction. The system architecture consists of multiple interconnected modules ensuring seamless conversion of natural language queries into SQL queries. The user inter-acts with the system via a web browser, accessing the Streamlit-based user interface. Through this interface, users can register, log in, and input natural language queries.User authentication and authorization are managed using SQLite, which securely stores user credentials and access permissions. Once authenticated, users can input natural language queries, which are processed by the natural language processing (NLP) module. This AI-powered module interprets user input and forwards it to the SQL generation module. The SQL generation module converts the processed query into a structured SQL command, using an API key stored in environment variables for secure access. The generated SQL query is then executed using the SQLite execution engine, retrieving the required data. For administrators, the system includes a dedicated admin panel built with Streamlit, providing access to user data stored in the SQLite database. Admins can manage user accounts and monitor query history. The system ensures security through role-based access control, environment variables for API security, and password encryption. The architecture maintains efficiency, accuracy, and scalability, making it a robust natural language-to-SQL solution.

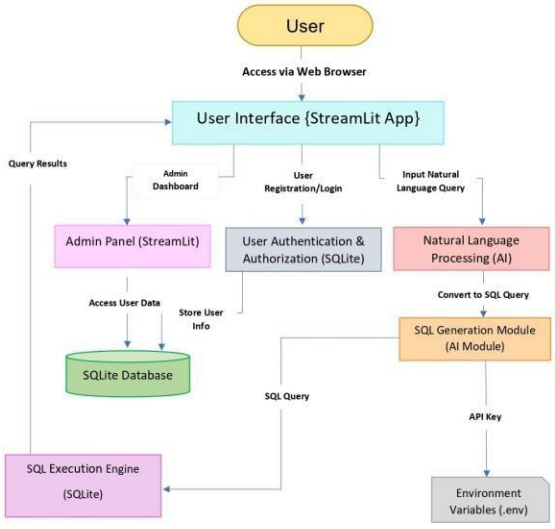

Fig. 1: System Architecture of the Natural Language to SQL Converter

D. Technical Details

The ”Natural Language to SQL Converter” web platform enables users to generate SQL queries from plain English inputs effortlessly. Leveraging AI, it translates natural language queries into accurate SQL code, making database interaction accessible to non-technical users. The system features a user-friendly interface built with Streamlit, allowing seamless input and query generation. The back-end, implemented in Python, integrates with SQLite for user management and query history. Additionally, an admin module provides access control and monitoring. By simplifying SQL query creation, SQL Converter empowers users to efficiently retrieve and manipulate data without requiring SQL expertise. Application Framework :The SQL converter is built on the Streamlit framework, chosen for its simplicity in developing interactive web applications. Streamlit’s Python-based structure allows for rapid prototyping and deployment. The framework also integrates seamlessly with various Python libraries and APIs, making it ideal for building a dynamic and user-friendly interface. AI Model Integration : The application leverages AI for natural language processing and SQL query generation. The model is accessed via API calls, where user input is processed and transformed into structured SQL syntax. By using the latest version of AI model textToSql, the system ensures high accuracy and performance. User Authentication and Role Management : User authentication is implemented using SQLite, a lightweight relational database system. The application features role-based access control, distinguishing between regular users and administrators. Authentication processes include login, registration, and secure password management. Admin users have additional privileges to view query histories and manage user accounts. Front-End Design : The front-end of the application is designed using Streamlit, focusing on a clean and intuitive user experience. Features include a text input area for natural language queries, a button to generate SQL code, and a dashboard displaying results. Back-End and Database Management : The back-end is developed in Python, utilizing the Streamlit framework for handling user interactions and displaying results. The application connects to SQLite to manage user credentials, store generated SQL queries, and log user interactions. Error handling mechanisms ensure that any issues during query generation are promptly communicated to the user. Security Measures : To safeguard user data, password hashing techniques are applied before storing credentials in the database. The application follows best practices for data security, including input validation and secure session management. Implementation : After implementing security measures, the project integrates all components into a fully functional application. The AI-powered Text-to-SQL converter is deployed within Streamlit, ensuring efficient query processing. The backend, including API communication for SQL generation, is linked with SQLite for data management. The authentication system is tested for secure login, registration,

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and role-based access. The front end is refined for usability, featuring an interactive dashboard and input fields. Extensive

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testing ensures query accuracy, error handling, and security compliance. Finally, the project is deployed on a server, with future enhancements planned for scalability and improved AI model performance.

IX. METHODOLOGY

The development of the Natural Language to SQL Converter application was carried out through a structured and systematic approach, ensuring efficiency, accuracy, and scalability. The methodology consisted of multiple stages, including requirement analysis, design, implementation, testing, and deployment. The first phase involves identifying and analyzing the specific needs of a project management system. This includes gathering requirements from stakeholders to understand functionalities like task management, team collaboration, progress tracking, and reporting. A feasibility study is conducted to assess the technical and economic viability of the system. The goal is to develop a user-friendly application that streamlines project management processes while providing real-time updates and data analytics.

A. Requirement Analysis and Design

- **Problem Definition and Feasibility Study:** The first phase involves identifying and analyzing the specific needs of a project management system. This includes gathering requirements from stakeholders to understand functionalities like task management, team collaboration, progress tracking, and reporting. A feasibility study is conducted to assess the technical and economic viability of the system. The goal is to develop a user-friendly application that streamlines project management processes while providing real-time updates and data analytics.
- **System Design and Architecture:** The system architecture was carefully designed to ensure modularity and scalability. The application follows a three-tier architecture comprising the front-end (Streamlit-based UI), back-end (Python Flask/Streamlit for request handling), and database (SQLite for storing user credentials and queries). The core component involves integrating AI to process natural language queries and generate corresponding SQL queries. Additionally, an admin module was incorporated to manage user access and view query history.

B. Development and Integration

- **Front-End Development:** The front-end was developed using Streamlit, providing a user-friendly and interactive interface. The application includes login, registration, and query input modules, ensuring smooth user interaction. The dashboard is dynamically designed with role-based navigation, offering distinct views for users and administrators.
- **Back-End and API Integration:** The back-end logic was implemented using Python to handle requests and process user queries. AI API was integrated to process natural language inputs and generate SQL queries dynamically.

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A robust API handling mechanism was put in place to en- sure seamless communication between the user interface and the AI model.

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- **User Authentication and Role Management:** SQLite was used to store and manage user credentials, with role- based access control for both regular users and admins. The login and registration modules were secured using hashed passwords to ensure data protection. Admin priv- ileges were granted selectively to manage the database effectively.
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Fig. 2: Home Page

B. User Registration

The User Registration page of the SQL Converter web application facilitates new user account creation. The left sidebar navigation includes links to Home, Registration, and Login, with the active page visually distinguished. The main content area contains a form with input fields for Username, Email, and Password, utilizing HTML form elements and CSS styling for user-friendly interaction. A checkbox labeled Register as Admin enables role-based account designation. The password field includes an eye icon toggle for visibility control via JavaScript. The Register button triggers a POST request to the backend for account creation, while the Go to Login Page button navigates to the login screen.

Fig. 3: Registration Page

C. User Login

This login page, crafted with Streamlit, presents a clean interface for user authentication. The left sidebar offers navigation to the home and registration pages, while the main section features a ”User Login” heading with a lock icon, emphasizing security. Users input their username and password into designated fields, with password visibility toggled by an eye icon. The ”Login” button triggers credential verification against an SQLite database. Successful logins grant access to the application, potentially redirecting users to the main app interface. The ”Deploy” button in the top right corner suggests Streamlit’s deployment capabilities.

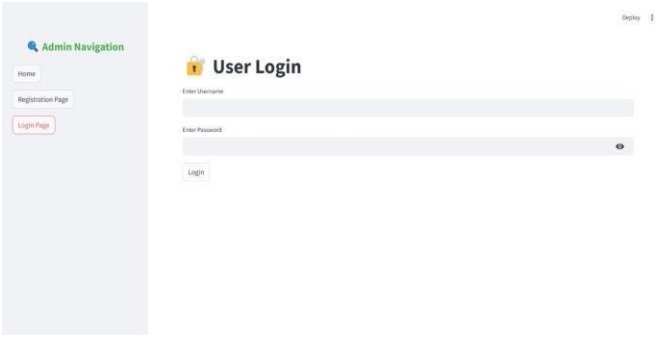

Fig. 4: Login Page

D. Generate SQL Query:Conversion Process

This part of the system’s main page is this, showcases a natural language to SQL conversion tool powered by AI Model. The user enters a plain English query, which is then sent to API. This AI, trained on extensive code and language data, interprets the user’s intent and translates it into a structured SQL query. The AI understands natural language constructs and maps them to corresponding SQL syntax and database operations. The generated SQL, representing the user’s request, is then displayed back to the user in a readable format, along with explanations of the data types used in the query. This process bridges the gap between human language and machine-executable database commands.

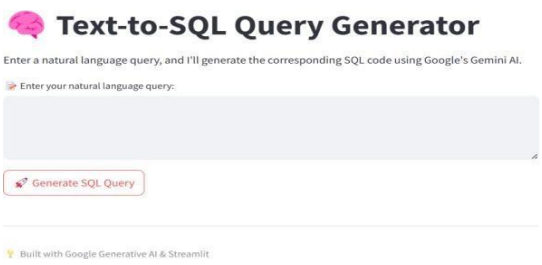

Fig. 4: Interface

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Fig. 5: example1

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E. Real-Time Query Processing and Error Handling

The application ensures efficient and real-time processing of user queries by leveraging asynchronous calls to the API. Once the SQL query is generated, the application validates the generated query to check for syntax errors and missing conditions.

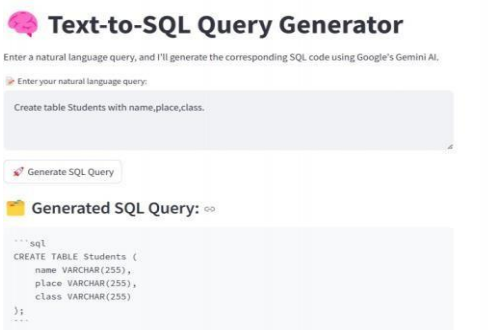

Fig. 6: example2

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We are extremely thankful to our Principal Dr. S.P. Subramanian for giving us his consent for this Mini Project We are thankful to Ms. Sreeshma K, Head of the Department and Dr. Hema P Menon, Dean(RD), Department of Computer Science Engineering, for their valuable suggestions and support. We are indebted to our Project Coordinator Mr.Anoop Aryan, Assoc.Professor and our guide Ms.Anjana M M., Asst. Professor, Dept.of Computer Science Engineering, for their constant help and support throughout the presentation of the survey by providing timely advices and guidance. We thank God almighty for all the blessing received during this endeavor. Last, but not least we thank all our friends for the support and encouragement they have given us during the course of our work.

CONCLUSION FUTURE SCOPE

This project demonstrates the viability of utilizing AI to translate natural language into SQL, simplifying database interaction through a web-based interface. The system's capacity to generate SQL from user input highlights the potential for accessible database operations, though accuracy is constrained by the lack of explicit schema incorporation. The project

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emphasizes the necessity of robust error handling and security protocols. This proof-of-concept serves as a foundation for developing intuitive, AI-driven database tools, aiming to democratize data access for a wider user base. Future development will focus on enhancing functionality and user experi- ence. Integrating direct schema retrieval and query execution will ensure real-time data interaction and accuracy. Advanced query handling, including complex SQL and database-specific syntax, will expand applicability. User interface refinements, like query history and voice input, will improve usability. Robust security measures are crucial. Multi-database support, image and query scanning, and Excel table handling will broaden functionality. An API for external integration and AI model refinement on larger datasets will improve accuracy, leading to a comprehensive, AI-driven database platform.This project demonstrates the viability of utilizing AI to translate natural language into SQL, simplifying database interaction through a web-based interface. The system's capacity to gener- ate SQL from user input highlights the potential for accessible database operations, though accuracy is constrained by the lack of explicit schema incorporation. The project emphasizes the necessity of robust error handling and security protocols. This proof-of-concept serves as a foundation for developing intuitive, AI-driven database tools, aiming to democratize data access for a wider user base. Future development will focus on enhancing functionality and user experience. Integrating direct schema retrieval and query execution will ensure real-time data interaction and accuracy. Advanced query handling, including complex SQL and database-specific syntax, will expand ap- plicability. User interface refinements, like query history and voice input, will improve usability. Robust security measures are crucial. Multi-database support, image and query scanning, and Excel table handling will broaden functionality. An API for external integration and AI model refinement on larger datasets will improve accuracy, leading to a comprehensive, AI-driven database platform.

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Face Recognition And Helmet Detection

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Abstract—The Face Recognition and Helmet Detection System is an advanced AI-powered so lution designed to enhance security, streamline user identification, and ensure safety compliance by detecting both human faces and the presence of helmets. The system leverages the power of Flask, OpenCV, and facerecognition libraries to facilitate real time facial recognition and helmet detection, making it suitable for environments where safety regulations must be enforced, such as construction sites, industrial workplaces, and traffic monitoring systems. The system is structured with multiple key components, including user enrollment, authentication, real-time recognition, and automated check-in logging. During the enrollment process, users submit im ages which are processed to extract and encode unique facial features for future recognition. These encoded face data are stored securely in a structured database and a serialized file to enable fast and efficient retrieval during recognition. The system also employs an admin dashboard that provides an intuitive interface for managing users, monitoring helmet compliance, and tracking attendance records. To ensure secure access, an authentication mechanism using Flask-Login is imple mented allowing only authorized administrators to manage the system. Once deployed, the system continuously monitors incoming images, detects hu man faces, and verifies them against the stored database using an efficient face matching algorithm. Simultaneously, the helmet detection module, powered by a pretrained Haar cascade classifier, scans the detected face region to determine whether a helmet is worn. If a user is recognized and helmet detection is successful, the system logs their check-in details, including user ID, name, check-in timestamp, and helmet status, into a structured database. The system ensures real-time record keeping, allowing administrators to monitor compliance effectively. Additionally, check-in records are formatted and displayed in a tabular format with time zone conversion to Indian Standard Time (IST), ensuring clear visibility of attendance and safety compliance data. The system also allows administrators to delete users when necessary by removing their facial data, stored images, and database records to maintain an up-to-date user database. Designed with efficiency and security in mind, the Face Recognition and Helmet Detection System offers a reliable, automated ap proach to identity verification and safety enforcement, making it an essential tool for organizations looking to maintain a safe and regulated environment.

I. Introduction

Safety and compliance in workplaces and educational institutions is a growing concern, necessitating the development of advanced automated monitoring systems. This project aims to create a robust system for face and helmet detection in both images and video streams. By leveraging cutting-edge computer vision and ma chine learning techniques, the system enhances security by accurately identifying individuals and verifying safety compliance in real-time.

The interim review serves as a crucial checkpoint, assessing the project's progress, challenges, and overall system performance. It provides an in-depth anal ysis of detection and recognition accuracy, as well as real-time processing efficiency. Through this review, key refinements are identified, ensuring the optimization of algorithms and system components to meet project objectives effectively.

Furthermore, this review outlines critical milestones and strategic adjust ments necessary to maintain project momentum. By addressing technical hurdles and streamlining implementation strategies, the project team ensures timely com pletion and deployment of a reliable, high-performance face and helmet detection system.

The system consists of a web interface, where admins can manage user enrollment, monitor real time face recognition, and view check-in records. On the backend, a Flask applica tion handles user authentication, face recognition using the face recognition library, and helmet detection with a pretrained Haar cascade classifier. Data is stored in an SQLite database, which includes user details, face encodings, and check-in logs. The workflow begins with user enrollment, where admins upload an image for face de tection and encoding, followed by real-time user identification and helmet detection. The system also automatically logs check-ins, noting helmet compliance. Admins can view and manage check-in records, ensuring both safety and accurate attendance tracking. The system provides a streamlined and efficient way to monitor workplace safety and manage user activity.

II. System Architechture

The system architecture is depicted in the figure 3.1. The Block diagram illustrates the flow of data and interactions between users, first aid responders, the database, and various system components. The proposed system is an automated solution designed to detect faces, recognize individuals, and identify helmet usage in real-time. It uses computer vision techniques, including Haar Cascade classifiers for face and helmet detection, and deep learning for facial recognition.The system's purpose is to enhance workplace safety by ensuring helmet compliance and improve security through accurate individual identification.Its functionality includes process ing video streams to monitor individual in real-time, providing

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alerts when safety protocols are not followed.The benefits include increased safety, operational effi ciency, and reduced manual oversight, ultimately leading to a safer and more secure environment. Key components: Camera/Video Feed: Captures real-time video or images for processing. Grayscale Conversion: Reduces complexity and enhances detection. Edge Detection: Highlights important features for accurate object detec tion. andFace Detection Haar Cascade Classifier: Detects faces using a pre-trained model. Function Used: cv2.CascadeClassifier.detectMultiScale(). Face Recogni tion Deep Learning Model (FaceNet): Converts detected faces into 128-dimensional embeddings. Recognition: Compares embeddings with stored database values for identification Helmet Detection Haar Cascade Classifier: Identifies whether a hel met is worn. Output Real-Time Display: Shows detected faces and helmets with bounding boxes.

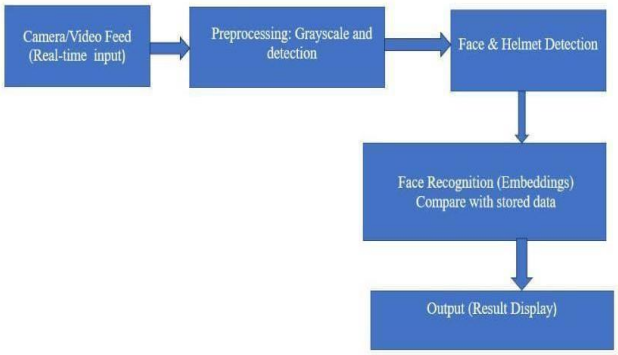

Fig. 1. System Architechture

III. Literature Review

Face recognition and helmet detection systems have gained significant attention with advancements in computer vision and deep learning techniques. Traditional methods relied on manual monitoring or rule-based image processing, which were time-consuming and prone to errors. Recent studies have leveraged deep learning based approaches, particularly convolutional neural networks (CNNs) and YOLO (You Only Look Once) object detection models, to improve accuracy and efficiency in recognizing faces and detecting helmets in realtime applications. Researchers have explored modifications to these models by incorporating hybrid AI techniques, attention mechanisms, and data augmentation strategies to enhance performance. The integration of facial recognition and helmet detection has gained traction in safety compliance systems. Early work by Prajapat et al [1] demonstrated this dual functionality for toll plaza monitoring, using face recognition to identify riders while verifying helmet compliance. Their framework established a foundational approach but relied on traditional Viola-Jones algorithms, which newer systems have sought to improve. Detection methodologies have evolved through computational enhancements. Sa tia Simbolon et al. [2] improved facial detection accuracy by 12 percentage using bicubic interpolation with Principal Component Analysis (PCA), a technique that could refine enrollment processes in modern systems. Preetham et al. [3] expanded helmet functionality by integrating alcohol detec tion sensors. Their system aimed to enhance road safety by preventing intoxicated individuals from riding motorcycles, illustrating the growing trend of combining safety gear verification with auxiliary features. Chen et al. [4] tailored their detection system for construction sites, focusing on accident prevention through advanced helmet and face detection mechanisms. Their work emphasized workplace safety by enforcing strict compliance policies in hazardous environments. Garad et al. [5] achieved 94 percentage accuracy using Faster R-CNN models in traffic scenarios, setting a benchmark that highlights the limitations of Haar cascades (typically 80-85 percentage accuracy) used in earlier implementations. Their study demonstrated the advantages of deep learning in real-world helmet detection tasks. S. N et al. [6] developed SafeFaceYOLO, which leverages YOLOv5 for simul taneous face and helmet detection at 45 FPS, outperforming traditional methods in both speed and accuracy. Their work focused on real-time detection, making it highly suitable for applications requiring rapid decisionmaking.Veena and Babu [7] designed a cloud-based system for ATM security, combin ing face mask and helmet detection with remote processing. While their approach enables scalability, it contrasts with localized systems that prioritize low latency and cost efficiency, such as the current framework using opensource libraries like OpenCV. Ka et al. [8] implemented a mask-and-helmet detection system using machine learning, achieving a 98 percentage F1-score but with higher latency (2.3 seconds) compared to edge-based systems. Their work highlights the trade-off between accu racy and processing speed in real-time safety monitoring applications.

IV. Technical Details

For accurate user identification, the system employs FaceNet, a deep learning model that extracts 128-dimensional embeddings from detected faces. These embeddings are then compared with stored data using the face recognition library built on Dlib. This approach ensures high accuracy in recognizing individuals, even under varying lighting conditions and facial orientations. To improve detection accuracy and processing speed, the system applies pre processing techniques using OpenCV. Images are converted to grayscale, and edge detection methods are used to enhance the features needed for identifi cation. The system is designed for real-time processing, allowing immediate analysis of video streams for continuous monitoring and detection. The backend is developed using Flask, a lightweight Python web framework that enables API-based communication between system components. The database is managed using SQLite and

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SQLAlchemy, where user details, face encodings, and check-in records are securely stored. Authentication is handled with Flask-Login, ensuring secure access for administrators. The system loads and stores facial encodings using the face recognition library, allowing fast retrieval and comparison of user data. Helmet detection is implemented using OpenCV's Haar Cascade classifier, uti lizing a pre-trained XML file (haarcascadehelmet.xml) to scan images for hel met presence. The detection process involves converting images to grayscale, extracting the head region, and applying detection algorithms to verify compli ance. If a helmet is detected, the system logs the information in the database for further processing. When a user submits an image, it is first converted into a NumPy array and processed in RGB format for face detection using the facelocations() function. If a face is detected, the system extracts its encoding and com pares it with stored data using comparefaces(). At the same time, helmet detection is performed by extracting the head region and applying helmetcas cade.detectMultiScale() to confirm the presence of a helmet. If a match is found, the system logs the user's ID, name, and helmet status in the database. If no match is detected, the individual is labeled as "Unknown." The system then generates a response displaying user details, recognition confidence score, and helmet status on the dashboard.

V. Dataset

System maintains a structured dataset of enrolled users to enable face recognition and safety compliance monitoring. Each entry includes three primary attributes: a unique User ID (numeric identifier), the user's name (textual identifier), and an Action field for administrative management, such as user deletion. This dataset acts as the core reference for facial authentication, connecting stored face encodings (in the file faceencodings.pkl) with user identities. Privacy is preserved by separating sensitive biometric data from personal identifiers, with deletion operations removing all associated records permanently. The dataset's tabular structure ensures scalabil ity and seamless integration with check-in logging and realtime detection modules, enabling automated tracking of helmet compliance and user activity. Example en tries include users like "nabeel," "shibila," and "aman," illustrating the system's capability to efficiently manage and authenticate individuals.

Fig. 2. Data Enrolling Page

VI. Experimental Result

A. Admin Login

The Admin Login feature ensures that only authorized personnel can access and manage the Face Recognition and Helmet Detection System. By default, the system provides an initial admin account with the credentials (Username: admin, Password: admin), which should be changed immediately after the first login for security reasons. Authentication is handled using Flask-Login, ensuring secure ses sion management. If incorrect credentials are entered, the system displays an error message to prevent unauthorized access. Upon successful login, the admin gains access to the dashboard, where they can manage users, view check-ins, and perform administrative tasks. A logout function is also available to securely end the session and redirect the admin to the home page, ensuring controlled access to sensitive system operations.

Fig. 3. Admin Page

B. Face Detection Phase

System performs real-time face recognition and identity verification through a multi-step workflow. When an individual's face is detected, the system captures the facial image and processes it using pre-trained models to extract unique facial fea tures. These features are compared against the stored face encodings in the dataset to identify a match. In this instance, the system recognized the user as "aman," indicating a successful match between the live input and his pre-registered facial data. Concurrently, the system validates safety compliance by checking for helmet presence using Haar cascade classifiers or similar detection algorithms. Upon confir mation of both identity and compliance, the ignition system is authorized, enabling access or operational control. This seamless integration of biometric authentication and safety checks ensures secure and policy-compliant user interactions in real-world applications.

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C. Helmet Detection Phase

System tracks user check-ins while simultaneously monitoring helmet compliance through integrated detection mechanisms. When a user's face is recognized (e.g., "nabeel" or "aman"), the system processes their live image using computer vision algorithms to identify whether a helmet is present. This detection is performed by analyzing the head region of the captured image, often employing Haar cascades or

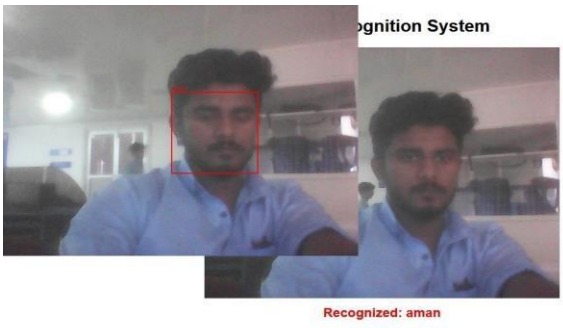

Fig. 4. Pace Detection Phase

deep learning models trained on helmet datasets. The result ("Helmet Exist: No" in these entries) is then logged alongside the user's ID, name, and precise check in timestamp. These records are stored in a structured database table, enabling administrators to audit safety compliance over time. The "Helmet Exist" column specifically highlights adherence to safety protocols, with "No" indicating a violation that could trigger alerts or corrective actions. This automated process ensures real time monitoring and historical tracking of safety measures, critical for workplaces or traffic systems requiring strict helmet policies.

Fig. 5. Helmet Detection Phase

VII. Conclusion

Face Recognition and Helmet Detection System provides a comprehensive solution for combining biometric authentication with safety compliance monitoring. By inte grating Flask for backend operations, OpenCV for helmet detection, and advanced facial recognition libraries, the system ensures accurate identification of users and enforcement of safety protocols. The administrative interface simplifies user man agement, while automated check-in logging maintains detailed records of compliance status. Key achievements include the seamless real-time integration of face recogni tion and helmet detection, scalable user enrollment processes, and privacyfocused data handling that separates biometric data from personal identifiers. This system addresses critical needs in environments requiring strict safety measures, such as industrial workplaces or traffic management systems, by offering a practical and adaptable tool for enforcing safety policies.

VIII. Acknowledgment

We are extremely thankful to our Principal Dr. S.P. Subramanian for giving us his consent for this Mini Project We are thankful to Ms. Sreeshma K., Head of the Department and Dr. Hema P Menon, Dean(RD), Department of Computer Science Engineering, for their valuable suggestions and support. We are indebted to our Project Coordinator Mr. Anoop Aryan, Asst. Professor and our guide Ms. Anjana M M, Asst. Professor, Dept.of Computer Science Engineering, for their constant help and support throughout the pre sentation of the survey by providing timely advices and guidance. We

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thank God almighty for all the blessing received during this endeavor. Last , but not least we thank all our friends for the support and encouragement they have given us during the course of our work.

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Pest Detection In Agriculture

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Abstract—Pest infestations pose a significant threat to agricultural productivity, leading to substantial economic losses and increased pesticide use. Traditional pest detection methods rely on manual observation, which is time-consuming, labor-intensive, and prone to human error. This project aims to develop an AIbased pest detection system using deep learning techniques to provide a more efficient and accurate solution. The system utilizes YOLOv8, a state-of-the-art object detection model, trained on the IP102 dataset, which consists of labeled images of various pest species. The trained model is integrated into a Flaskbased backend, which processes images uploaded through an Angular-based web interface. Upon image submission, the model detects and classifies pests in real-time, providing users with the pest's unique id and confidence score. The implementation of this system enhances pest monitoring, reduces excessive pesticide usage, and promotes sustainable farming practices. Future enhancements include expanding the dataset, optimizing the model for mobile and edge devices, and integrating AI-driven pest control recommendations. This project demonstrates the potential of AI and deep learning in transforming agricultural pest management by providing an automated, scalable, and userfriendly solution.

I. Introduction

Agriculture is a fundamental sector that ensures food security and economic stability worldwide. However, one of the major challenges faced by farmers is pest infestations, which significantly reduce crop yields and lead to financial losses. Pests can spread rapidly and cause irreversible damage if not detected and controlled in time. pest detection is crucial for minimizing crop damage and enabling farmers to take timely preventive measures. Traditional methods, such as manual inspection, are time-consuming, labor-intensive, and prone to errors, making them inefficient for large-scale farming. There is a growing need for automated, technology-driven solutions that can accurately and efficiently detect pests. This project aims to develop a deep learning-based pest detection system using YOLOv8 (You Only Look Once version 8), a state-ofthe-art object detection algorithm. The system processes images of crops, identifies different types of pests, and provides real-time results, allowing farmers to make quick and informed decisions. By leveraging deep learning techniques, this project seeks to improve pest detection accuracy, reduce reliance on manual inspection, and promote sustainable farming practices by optimizing pesticide usage. The implementation of such an intelligent system can help increase crop productivity, reduce losses, and support precision agriculture.

II. Literature Review

Pest detection in agriculture has evolved significantly with advancements in deep learning techniques. Traditional methods relied on manual inspections, which were time-consuming and error-prone. Recent studies have leveraged YOLOv8, a state of-the-art object detection model, to enhance the accuracy and efficiency of pest identification in various crops. Researchers have explored modifications to YOLOv8 by incorporating attention mechanisms, transformer encoders, and hybrid AI techniques to improve performance. Tang et al. [1] introduced an improved pest detection model using YOLOv8 with an efficient channel attention mechanism and transformer encoders. Their study demonstrated a significant increase in detection accuracy while reducing false positives. Similarly, Yang et al. [2] developed a YOLOv8-based system for rice pest detection, integrating data augmentation techniques to enhance the model's robustness against environmental variations. Their approach led to higher detection rates in diverse field conditions. Further advancements were made by BASAY et al. [3], who proposed a hybrid model combining YOLOv8 with ChatGPT-3 for organic pest control. Their study focused on detecting Theba pisana (a type of snail) on eggplants, showcasing the potential of AI-driven solutions in sustainable farming. The integration of large language models allowed for real-time expert advice, aiding farmers in effective pest management strategies. Yin et al. [4] optimized YOLOv8 by introducing a lightweight architecture with improved attention mechanisms. Their model significantly reduced computational requirements while maintaining high detection accuracy, making it ideal for real-time applications in large-scale farming. In a related study, Chen et al. [5] incorporated BiFormer attention mechanisms into YOLOv8, enhancing pest detection precision in complex agricultural environments. Their research, presented at ICCVDM 2024, highlighted the potential of

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attentionbased models in improving object detection tasks. Yue et al. [6] extended the application of YOLOv8 to forestry pest detection by developing GLU-YOLOv8, an improved variant designed for small pest detection in dense vegetation. Their approach demonstrated superior performance in identifying pests in complex natural settings, making it a valuable tool for automated pest monitoring.

III. Proposed System

A. problem statement

Pest infestations pose a significant challenge in agriculture, leading to reduced crop yield, financial losses for farmers, and increased reliance on chemical pesticides that harm the environment. Traditional pest detection methods involve manual inspection, which is time-consuming, labor-intensive, and prone to human error. Inconsistent identification of pests can lead to ineffective pest control strategies, resulting in excessive pesticide use and crop damage. There is a need for an automated, accurate, and efficient pest detection system that can quickly identify different types of pests and assist farmers in taking timely action to mitigate crop losses.

B. System Architecture

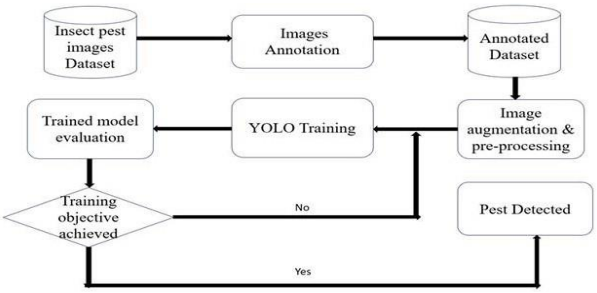

Fig. 1. Data Flow Diagram

The system architecture is depicted in Figure.1 The diagram illustrates the flow of data and interactions between different components involved in the pest detection process. It outlines the step-by-step workflow, starting from dataset collection to model training and evaluation. The system integrates multiple stages, including image annotation, data preprocessing, model training, and evaluation, ensuring an iterative approach to enhance detection accuracy. This structured pipeline enables efficient pest identification, leading to improved agricultural monitoring and pest control solutions. The system architecture for the pest detection model using YOLO follows a structured pipeline to ensure accurate training and detection. The process begins with an insect pest images dataset, which contains images of various pest species. These images undergo an annotation phase where bounding boxes are drawn around pests to create an annotated dataset, enabling the model to learn the location and classification of pests. Following this, the dataset undergoes image augmentation and pre-processing techniques such as scaling, flipping, and contrast adjustments to enhance model generalization. The pre-processed images are then fed into the YOLOtraining phase, where the model learns to detect and classify pests effectively. Once the model is trained, it enters the evaluation phase to assess its performance. If the accuracy is unsatisfactory or the false detection rate is high, the model undergoes further training with adjusted parameters in an iterative manner. This process continues until the training objective is achieved, ensuring an optimized detection system. Upon achieving the desired accuracy, the model is deployed for real-world applications, where it detects pests in agricultural fields. The final output aids farmers and agricultural professionals in identifying and managing pest infestations efficiently. This structured and iterative learning process ensures high accuracy and reliability, making the system effective for real-time pest detection in agricultural settings.

IV. TECHNICAL DETAILS

The technical implementation of this project involves a combination of deep learning, web development, and backend integration to create an efficient pest detection system. The system is built using Python for deep learning and backend processing, while Angular is used for the frontend interface. YOLOv8, a state-of the-art object detection model, is trained on the IP102 dataset to accurately identify pests in agricultural images. The architecture includes a Flask-based backend for model inference and an interactive web interface for user input. The project is developed using Python for backend processing and Angular for the frontend. Python is used for training and deploying the deep learning model, while Flask serves as the backend framework for handling requests and executing model inference. The frontend is built using Angular to provide a dynamic and user-friendly interface. The system utilizes YOLOv8 (You Only Look Once, version 8), an advanced object detection algorithm known for its high accuracy and real-time processing capabilities. The model is trained using the IP102 dataset, which consists of labeled pest images from various agricultural environments. It is optimized using techniques such as data augmentation and hyperparameter tuning to improve performance.The IP102 dataset is used for training, validation, and testing. Preprocessing steps include image resizing, normalization, and data augmentation (rotation, flipping, brightness adjustment) to improve model robustness. The dataset is split into 80% for training, 10% for validation, and 10% for testing. The architecture consists of a three-tier structure: the frontend, backend, and deep learning model. The Angular-based frontend allows users to upload images, which are sent to the Flask backend for processing. The backend forwards the images to the YOLOv8 model, which performs object detection and returns results, including

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detected pests and confidence scores. The trained YOLOv8 model is deployed on a Flask server, making it accessible for real-time inference. The application is hosted on a cloud or local server to enable scalability and accessibility for users. The model inference is optimized to reduce latency and ensure quick response times.

V. DATASET

The dataset used for this project is the IP102 (Insect Pest 102) dataset, a large-scale benchmark dataset for pest detection in agriculture. It consists of approximately 6000 images covering 95 different pest species, making it one of the most comprehensive datasets available for agricultural pest identification. The images are collected from real-world agricultural environments and online sources, with annotated bounding boxes to accurately locate pests within each image. The dataset is structured into training, validation, and testing sets, with a 80-10-10effective model learning and evaluation. Before training, preprocessing steps such as image resizing, data augmentation (flipping, rotation, brightness adjustments), and normalization were applied to enhance model performance and generalization. Despite its usefulness, challenges such as class imbalance, varying image quality, and complex backgrounds were encountered, requiring additional preprocessing and data enhancement techniques. This dataset serves as a crucial component in training the YOLOv8-based pest detection model, enabling efficient and accurate identification of pests to support sustainable agriculture.

Features	Description
Dataset Name	IP102 (Insect Pest 102)
Total Images	Approximately 6000
Number of Pest Categories	95 different species
Dataset Splitting	80% training, 10% validation, 10% testing

Fig. 2. Dataset

VI. EXPERIMENTAL RESULT

A. image upload module

The user clicks on the ”Choose File” button. A file selection window appears where the user selects an image of the crop. Supported image formats: JPEG, PNG.

Fig. 3. User Interface for Image Upload

B. detection result

The processed image is displayed on the screen with detected pests high lighted using bounding boxes. The unique ID of the detected pest and its confidence level are shown. If no pest is detected, the system notifies the user.

Fig. 4. Result

VII. CONCLUSION AND FUTURE SCOPE

The development of pest detection system using YOLOv8 provides an efficient and accurate solution for identifying agricultural pests. By leveraging deep learning techniques and a well-labeled dataset like IP102, the system ensures precise pest classification, helping farmers take timely action to protect their crops. The integration of a Flask backend for model inference and an Angular-based frontend enhances usability, making the system accessible to farmers and agricultural professionals. This approach not only minimizes manual labor and human error in pest identification but also reduces the overuse of chemical pesticides, contributing to sustainable farming practices. The project demonstrates how AI-driven solutions can significantly improve pest management, ultimately leading to increased crop yield and economic benefits for farmers.

In the future, the system can be enhanced in multiple ways to improve accu racy, usability, and scalability. Expanding the

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dataset with more diverse pest images under varying environmental conditions can enhance model robustness. Implementing a mobile application can improve accessibility for farmers in remote areas. Integrating Internet of Things (IoT) devices, such as drones and smart cameras, can enable real-time pest monitoring over large agricultural fields. Additionally, incorporating predictive analytics and early warning systems can help farmers prevent pestoutbreaks before they cause severe damage. Further advancements in AI models, such as transformer-based vision models, can also be explored to improve detection accuracy and speed.

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COMPREHENSIVE SURVEY ON EEG SIGNAL CLASSIFICATION BASED ON TIME-FREQUENCY ANALYSIS AND MACHINE LEARNING TECHNIQUES

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Abstract—Epileptic seizure prediction and classification are crucial for improving patient care and early intervention. Countless studies have surveyed different machine learning approaches to classify electroencephalogram(EEG) signals into ictal, interictal and preictal. This survey examines a representative methodology that leverages time-frequency feature extraction and supervised learning for seizure state classification. The workflow of this survey begins with the signal preprocessing, include bandpass filtering,channel averaging, and segmentation.Discrete Wavelet Transform (DWT) is used for feature extraction, particularly with Daubechies 4 (db4) wavelet is applied at level 4 decomposition, which effectively captures time-frequency features from signal. The extracted features are typically stored in a CSV file and used to train a random forest model. Labels for training are derived from annotated seizure times. This pipeline demonstrates a robust and interpretable framework for seizure stage classification. By synthesizing such approaches, this survey highlights the potential of time-frequency domain analysis and ensemble learning models in advancing automated seizure detection and prediction systems.

I. Introduction

Electroencephalography(EEG) is a widely used neurophysiological monitoring technique that records electrical activity in the brain. EEG signal classification plays a crucial role in various applications, including brain-computer interfaces (BCIs), seizure detection, mental state analysis, and cognitive research. However, EEG signals are highly complex, nonstationary, and prone to noise, making accurate classification a challenging task. Epilespy is a chronic neurological disorder characterized by recurrent seizures, which are sudden and unprovoked electrical disturbances in the brain. Identifying and classifying different stages of epileptic activity, such as ictal(during a seizure), interictal(between seizure), and preictal(before a seizure), is crucial for effective diagnosis, treatment planning and seizure prediction.

Traditional machine learning (ML) techniques, such as support vector machines (SVM), k-nearest neighbors (KNN), and deep learning models like convolutional neural networks (CNNs) and recurrent neural networks (RNNs), have been widely adopted for EEG classification. These models relay on extensive feature extraction and labeled datasets for supervised learning.

This survey mainly focused on classifying the EEG signal is a hybrid methodologies that combines time frequency features and annotated seizure timings in the dataset. Discrete Wavelet Transform (DWT), particularly using Daubechies wavelets, are frequently used to capture the dynamic frequency content of EEG signals across multiple temporal scales. These extracted features, when paired with robust classifiers like Random Forests, have yielded high classification accuracy in distinguishing epileptic stages. This survey aims to provide a focused overview of such methodologies, highlighting the effectiveness of time-frequency feature extraction and ensemble learning models in seizure state classification.

By recording the electrical activity of the brain, electroencephalography (EEG) is still a vital diagnostic and monitoring tool for epilepsy. Traditional manual interpretation of EEG data, however, is frequently time-consuming, labor-intensive, and subject to subjectivity. The automated classification of EEG signals, which provides reliable, impartial, and effective analysis for seizure detection and prediction, has drawn more attention from researchers in an effort to get around these restrictions. The complexity and variability of epileptic patterns, noise and artifacts in EEG recordings, and the need for efficient feature extraction and selection are some of the obstacles that automated EEG classification must overcome despite its potential. As a result, a range of computational approaches have been investigated, from complex signal processing techniques and ensemble learning strategies to traditional machine learning algorithms. These methods seek to improve clinical decision-making, encourage real-time monitoring, and increase classification accuracy. In order to increase real-world applicability, current research efforts focus on creating strong classification frameworks, using suitable evaluation metrics, and looking into preprocessing and feature engineering techniques. All things considered, automated EEG signal classification has become a crucial field of research for improving seizure management and epilepsy diagnosis.

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Wei Zhang, Xianlun Tang1 and Mengzhou Wang[1] This research examines how brain-computer interfaces (BCIs) utilize EEG signals to control devices, focus on advanced signal processing and machine learning for accurate seizure detection.Muhammad Haseeb Aslam 1, Syed Muhammad Usman[2] It enhances accuracy and computational efficiency by focusing on key signal features, making it particularly suitable for real-time BCI applications and seizure prediction. Hafeez Ullah Amin, Wajid Mumtaz[3] The work is concerned with EEG-based brain-computer interfaces by employing machine learning and pattern recognition to enhance brain signal classification. Feature extraction and real-time monitoring are highlighted in order to increase accuracy for clinical as well as assistive applications such as diagnostics and neurorehabilitation. Maria Camila Guerrero, Juan Sebasti an Parada[4] The study aims to compare four machine learning models, logistic regression, ANN, SVM, and CNN, to classify EEG signals in being an epileptic or non-epileptic state. It highlights that EEG signals features are Fourier-based and that ANNs had the highest accuracy (86%) which can help produce reliable EEG signal-based diagnostics. Prasath, A.S.S, Lokesh[5] This article discusses machine learning and deep learning methods- such as logistic regression, ANN, SVM, and CNN- for the classification of EEG signals that use Discrete Wavelet Transform for feature extraction, and provides a comparative performance assessment with recommendations as to which models were most likely to accurately diagnose EEG data. Mohammed Yousif, Iman Ameer Ahmad[6] The paper offers a new classification method for EEG data using modified DWT for feature extraction, Gray Wolf Optimization for feature selection, and a hybrid SVM-NN model for classification. The authors achieved 97% accuracy, and it offers a reliable method for BCI applications and neurological diagnostics. Also, it aligns well with the EEG preprocessing and classification requirements of your project. Swati Chowduri, Satadip Saha Samadrita Karmakar[7] This article describes a real-time EEG classification system for use on portable devices that utilized machine learning to monitor student attitional engagement. Author's description of real-time data processing, model resampling, temporal interpolation and model deployment, as well as educational applications may provide useful insights when developing your responsive BCI or neurofeedback systems. Hepseeba kode, Khaled Ellety[8] The article discusses machine and deep learning methods for detection of epileptic seizures with EEG signals, emphasizing relevant feature extraction processes (e.g. wavelet transforms) and rigorous performance evaluation. It provides a brief overview of the most relevant methods for building real-time seizure detection systems that accurately detect seizure events with good performance applicable to your project goals. Remy Ben Messaoud, M Chavez[9] A strong machine learning approach using a Random Forest model and handcrafted features is proposed in the paper to predict epileptic seizures from EEG data. The proposed method is evaluated on the CHB-MIT and Kaggle datasets and exhibits strong performance because of a high accuracy (up to 89.31% sensitivity and 0.03/h false positive rate) due to careful preprocessing, feature extraction, artifact rejection and a new alarm-raising method. The paper argues the importance of methodological rigor and personalization for producing results that are clinically relevant for real-time prediction of seizures. A. T. Tzallas, M. G. Tsipouras, and D. I. Fotiadis[10] Using time-frequency (T-F) analysis methods like Cohen's class distributions and the Short-Time Fourier Transform, this paper suggests a way to identify epileptic seizures in EEG signals. Using artificial neural networks, it classifies EEG segments and extracts energy-based features from the time-frequency plane, achieving high accuracy on a variety of classification tasks. Z. Iscan, Z. Dokur, and T. Demiralp[11] In order to classify EEG signals, this paper combines frequency-domain features extracted using power spectral density (PSD) with time-domain features obtained from cross-correlation. Using a benchmark epileptic EEG dataset and Least Squares Support Vector Machines (LS-SVM), the study shows that combining both feature types greatly increases classification accuracy, reaching up to 100% accuracy. D. Gajic, Z. Djurovic[12] This study investigates an automated method of identifying epileptic activity in EEG signals by combining wavelet, time, frequency, and non-linear analysis features, such as Lyapunov exponents. They use a quadratic classifier to classify the features after reducing their number using scatter matrices. M. Yousif, I. A. Ahmad [13] A hybrid method for categorizing EEG signals is presented in the paper. Wavelets are used to extract features, Gray Wolf Optimization is used to select the best features, and a combination of SVM and neural networks is used for classification. It outperforms many other models with an accuracy of 97% on EEG data associated with language tasks. M. Musselman and D. Djurdjanovic [14] With the help of binary SVM subproblem modeling, class-specific feature selection, and features taken from bilinear time-frequency distributions of EEG signals, this paper suggests a novel epilepsy classification algorithm. The technique demonstrates consistent accuracy across different training data proportions and outperforms current methods on benchmark data. K. Samiee, P. Kovacs [15] A novel Rational Discrete Short-Time Fourier Transform (DSTFT) for adaptive, localized time-frequency feature extraction from EEG signals is used in this paper to present an epileptic seizure detection system. The method outperforms several state-of-the-art techniques in terms of accuracy and compactness of EEG representation. A multilayer perceptron is used to classify the extracted features. A. T. Tzallas, M. G. Tsipouras [16] In this work, time-frequency (TF) analysis and artificial neural networks (ANNs) are used to automatically identify epileptic seizures in EEG signals. The method outperforms current techniques on a publicly available dataset by extracting features from TF representations of EEG segments and classifying them with high accuracy (up to 100% in some cases).

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T. Tzallas, M. G. Tsipouras, and D. I. Fotiadis [17] This study presents a novel technique that uses artificial neural networks (ANNs) and time-frequency (TF) analysis to identify epileptic seizures in EEG recordings. The method achieves high classification accuracy (up to 100% in some cases) across various seizure detection scenarios by extracting features from TF distributions to represent EEG energy patterns. In order to show how effective different TF distributions are for automated seizure detection, the study compares them. [18] The Hilbert-Huang Transform (HHT), which combines the Hilbert Transform and Empirical Mode Decomposition (EMD) to extract instantaneous frequency and amplitude features, is used in this paper to classify seizure and non-seizure EEG signals. The suggested method outperforms conventional methods like Multivariate EMD in separating epileptic seizures from normal brain activity, achieving high accuracy (94%) and specificity (96%) in the process. The tool is praised for its affordable price, easy-to-use interface, and real-time applicability. K. K. Dutta, P. Manohar [19] This study uses raw EEG signals from three datasets: Freiburg Hospital (FH), CHB-MIT, and Temple University Hospital (TUH) to propose a convolutional neural network (CNN)-based method for classifying epileptic seizure stages (preictal, ictal, postictal, and interictal). The model shows promise for automated seizure stage detection without preprocessing by achieving high accuracy (up to 94.02% for TUH) in binary and multi-class classification. The study demonstrates how well CNN handles unprocessed EEG data, providing a useful tool for patient monitoring and clinical diagnosis. M. Naeem, S. T. H. Rizvi [20] A thorough introduction to Reinforcement Learning (RL) is given in this paper, which covers basic ideas such as Markov Decision Processes (MDPs), important RL algorithms (such as Q-learning, SARSA, and Actor-Critic), and their uses in a variety of industries, including computer vision, robotics, healthcare, and the Internet of Things. It is a useful tool for both novices and researchers because it also covers issues and potential paths in reinforcement learning.

II. OBSERVATIONS

A. *Time-Frequency Analysis is Highly Effective for Seizure Detection*:

In EEG-based seizure detection, time-frequency (T-F) representations have become extremely effective tools. Numerous studies [10], [16], [17] highlight how well techniques like the Short-Time Fourier Transform (STFT) and Cohen's class distributions capture non-stationary patterns linked to epileptic episodes. When paired with Artificial Neural Networks (ANNs), these T-F features have shown remarkable performance, attaining classification accuracies of up to 100% [10], [16], [17]. Additionally, Rational Discrete STFT (DSTFT), which was first presented in [15], offers a localized and adaptive T-F representation that outperforms conventional T-F techniques and yields a more condensed and informative EEG characterization.

B. *Hybrid Feature Extraction & Selection Improves Performance:*

Because wavelet-based techniques can analyze EEG signals on a variety of scales, they still dominate feature extraction. Particularly in seizure classification tasks, Discrete Wavelet Transform (DWT) has demonstrated impressive performance [5], [6], [8], [12], [13]. Studies such as [6], [13] report up to 97% accuracy when DWT is coupled with metaheuristic feature selection algorithms like Gray Wolf Optimization (GWO). In addition to wavelets, hybrid feature sets that incorporate nonlinear dynamics (like Lyapunov exponents), time-domain, and frequency-domain (like power spectral density) have been shown to improve classification robustness [11], [12]. Furthermore, the Hilbert-Huang Transform (HHT) has been investigated for the extraction of instantaneous frequency features; its 94% detection accuracy [18] demonstrates its potential for capturing dynamic, complex signal behaviors.

C. *.Machine Learning Models Perform Well, but Deep Learning is Emerging:*

Seizures can still be detected using conventional machine learning models. Because of their interpretability and resilience, Random Forest (RF) and Support Vector Machines (SVM) are extensively used. For example, [9] uses handcrafted features with RF to achieve 89.31% sensitivity and a low false alarm rate, while [14] uses a binary SVM with class-specific feature selection to increase generalizability. But deep learning techniques are becoming more popular, especially for end-to-end EEG classification. When it comes to multi-class seizure stage classification, Convolutional Neural Networks (CNNs), as employed in [19], can process raw EEG directly without the need for preprocessing, attaining 94.02% accuracy. According to comparisons in [4], [5], ANNs can achieve up to 86% accuracy, outperforming traditional models like logistic regression and SVMs.

D. *Real-Time Applicability & Clinical Feasibility:*

A focus on real-time applicability is necessary when converting research models into clinically feasible solutions. The significance of low-latency processing and realistic implementation in seizure prediction systems is emphasized in works like [7], [9], [18]. Notably, [18] highlights accessibility and efficiency by showcasing an affordable, user-friendly system built on HHT. The system's clinical relevance is further enhanced by alarm-triggering mechanisms added in [9], which facilitate prompt intervention. Furthermore, research [15], [16] emphasizes the computational effectiveness of T-F analysis techniques,

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making them viable options for incorporation into real-time brain-computer interface (BCI) systems.

III. CONCLUSION & FUTURE SCOPE

For EEG-based seizure classification, the reviewed research papers show that time-frequency (T-F) analysis in conjunction with machine learning (ML) and deep learning (DL) models is very effective. While models like Support Vector Machines (SVM), Random Forest (RF), Artificial Neural Networks (ANN), and Convolutional Neural Networks (CNN) achieve high accuracy (up to 100% in some cases), Techniques like Short-Time Fourier Transform (STFT), Wavelet Transforms (DWT), and Hilbert-Huang Transform (HHT) offer robust feature extraction. Performance is further improved by hybrid techniques, such as wavelet-based feature extraction combined with Gray Wolf Optimization (GWO) for feature selection. Furthermore, it is possible to develop real-time seizure detection and prediction systems; some studies have included effective preprocessing and alarm mechanisms for clinical implementation.

Notwithstanding these developments, there are still issues with computational effectiveness, generalization across various EEG datasets, and reducing false alarms in practical applications. To further enhance seizure detection systems, future studies should investigate automation and adaptive learning.

Proximal Policy Optimization (PPO) and Hierarchical RL are two sophisticated reinforcement learning (RL) approaches that should be investigated in future automated seizure classification research to improve adaptability in dynamic EEG environments. Lifelong learning from streaming EEG data can be achieved through self-supervised pre-training and continuous reinforcement learning, and federated RL frameworks may allow for multi-institutional cooperation without jeopardizing patient privacy. Optimizing lightweight RL models (like quantized DQN) for edge devices will be crucial for real-world deployment. Furthermore, clinical trust can be enhanced by combining RL with explainable AI (XAI) techniques like uncertainty estimation and attention mechanisms. Lastly, hybrid neuro-symbolic techniques that integrate RL with domain expertise could improve the interpretability and accuracy of seizure prediction.

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Blockchain Based Voting System

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Abstract—Ablockchain-based voting system is a decentralized and transparent mechanism de signed to ensure the security, integrity, and accessibility of elections. By leveraging blockchain technology, votes are recorded on a tamper-proof distributed ledger, elim inating the risks of fraud and manipulation. Each vote is encrypted and linked to a cryptographic hash, ensuring anonymity while allowing public verification of results. Smart contracts automate election rules, preventing unauthorized changes and en forcing transparency throughout the voting process. Unlike traditional voting meth ods, which rely on centralized authorities, this system empowers voters with trust less, verifiable participation, making elections more secure and inclusive.Blockchain based voting systems are transforming elections by ensuring security, transparency, and accessibility. Unlike traditional voting methods, which rely on centralized au thorities, blockchain records each vote on a decentralized ledger, making it tamper proof and verifiable. Smart contracts automate election processes, enforcing rules and preventing fraud without the need for intermediaries. Voter anonymity is pre served through cryptographic encryption, while the public ledger allows realtime auditing of results. As this technology evolves, blockchainbased voting is poised to become a reliable and scalable solution, enhancing trust in democratic processes worldwide

Keywords—Blockchain, E-voting, Smart Contracts, Cryptographic Security, Distributed Ledger.

I. Introduction

In an era where digital transformation is reshaping industries, the electoral process remains one of the most critical systems requiring innovation. Traditional voting methods, whether paper-based or electronic, have long faced challenges re lated to security, transparency, voter accessibility, and trust. Issues such as voter fraud, tampering, and centralized control raise concerns about the credibility of elec tions. A blockchainbased voting system emerges as a revolutionary solution, ad dressing these vulnerabilities through decentralization, cryptographic security, and immutable record-keeping. By leveraging blockchain technology, votes are securely recorded on a distributed ledger, making them resistant to manipulation while en suring transparency and integrity in the electoral process. Blockchain-based voting systems operate on the principles of decentraliza tion and cryptographic verification, eliminating the need for a central authority to manage and validate votes. Each vote is encrypted, timestamped, and stored across multiple nodes in the blockchain network, ensuring that no single entity can alter or delete records. This distributed nature enhances security and reliability, as all transactions are publicly verifiable while maintaining voter anonymity. Additionally, blockchain technology enables remote and tamper-proof voting, expanding accessi bility for voters who may face barriers to participating in traditional elections. Smart contracts, self-executing agreements stored on the blockchain, further enhance security by automating election processes, including voter verification, bal lot casting, and result computation. These automated protocols reduce human interference, minimizing errors and preventing election fraud. As democratic in stitutions continue to explore the potential of blockchain voting, this technology promises a future where elections are more secure, transparent, and accessible to voters worldwide. By adopting blockchain-based voting systems, governments and organizations can reinforce public trust in democratic processes while ensuring fair and verifiable elections

II. Motivation

The motivation driving need for a secure, transparent, and tamper-proof vot ing system has never been more critical in modern democracies. Traditional voting 1 methods often face challenges such as fraud, voter suppression, and manipulation, undermining public trust in electoral outcomes. The rise of digital technologies presents an opportunity to address these issues, yet centralized electronic voting systems remain vulnerable to cyber threats and data breaches. Blockchain-based voting systems offer a revolutionary alternative by ensuring decentralization, veri f iability, and enhanced security. By leveraging blockchain's immutable ledger and cryptographic protocols, this system can restore confidence in elections, empower voters, and create a more inclusive and fraud-resistant electoral process. The mo tivation behind adopting blockchain in voting is to establish a fair, accessible, and transparent system that upholds the core principles of democracy while leveraging cutting-edge technology for a more secure future

III. Objectives

This project aims to: The primary objective of a blockchainbased voting system is to establish a secure, transparent, and tamper-resistant electoral process. By leveraging the de centralized nature of blockchain technology, the system ensures election integrity by preventing fraud, manipulation, and unauthorized alterations to votes. Every vote is securely recorded on an immutable ledger, providing a

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verifiable and auditable election process that fosters public trust. This increased transparency enhances voter confidence, as participants can independently verify their votes without com promising anonymity. Furthermore, the system aims to improve the efficiency and accessibility of elec tions by streamlining result processing and reducing administrative costs. Tradi tional voting systems often involve manual counting, logistical challenges, and de lays, whereas blockchain automates key processes, enabling faster and more accurate results. Additionally, blockchainbased voting opens up new opportunities for re mote and digital participation, ensuring inclusivity for individuals who face barriers to traditional voting methods, such as those living in remote areas or with dis abilities. Ultimately, this technology-driven approach aspires to revolutionize the electoral landscape by making elections more secure, transparent, efficient, and ac cessible for all. Key Objectives: 1. Election Integrity and Security– Ensures a tamper-resistant voting process by leveraging blockchain's decentralized and immutable ledger to prevent fraud and manipulation. 2. Transparency and Verifiability– Enhances public trust by allowing voters to verify their votes without compromising their anonymity, ensuring a transpar ent and auditable election process. 3. Efficiency and Accuracy– Streamlines vote counting and result processing through automation, reducing human errors, administrative costs, and delays associated with traditional voting methods. 4. Accessibility and Inclusivity– Enables remote and digital participation, mak ing voting more accessible for individuals facing geographical, physical, or logistical barriers 5. Cost Reduction and Sustainability– Minimizes the expenses associated with traditional voting infrastructure, such as paper ballots and polling stations, while promoting a more ecofriendly and technology-driven electoral system.

IV. Literature Review

Several studies have proposed blockchain as a transformative tool in electronic voting: *Several studies have explored the use of blockchain technology in electronic voting systems to improve security, transparency, and decentralization.

*Farooq et al. proposed a framework to make voting systems transparent using blockchain technology. Their main objective was to enhance transparency in voting by leveraging the immutable and decentralized nature of blockchain.

*Singathala, Narayansetty, and Kata developed a Blockchain-Based E-Voting System aiming to build a secure and efficient electronic voting mechanism. Their work focused on reducing fraud and ensuring the integrity of votes.

*Naik, Prajapati, Pandey, and Mishra examined the potential of blockchain in e-voting systems. Their research emphasized the innovative role of blockchain in improving the trustworthiness of voting applications.

*Arora, Ruchi, and Wasson designed a Blockchain-Based Voting Decentralized Application. The main focus of their study was to create a secure, decentralized voting environment free from central authority control.

*Al-madani et al. proposed a Decentralized E-Voting System Based on Smart Contracts. This system used blockchain technology along with smart contracts to implement tamperproof and transparent election procedures. .*Kamran, Nasir, Imran, and Yang conducted a Study on EVoting Systems and proposed a blockchain-based approach.
Their analysis compared various systems and highlighted blockchain's strengths in improving reliability and security in voting.

V. Proposed System

A. System Overview

The proposed blockchain-based voting system is designed to enhance secu rity, transparency, and efficiency in elections by utilizing decentralized ledger tech nology. Unlike traditional voting methods that rely on centralized authorities, this system ensures that votes are immutable, verifiable, and tamperproof. The pro cess begins with secure voter registration and authentication, where digital identity verification mechanisms such as biometric authentication, cryptographic keys, or ZeroKnowledge Proofs (ZKP) ensure voter legitimacy. Each registered voter is assigned a unique blockchain wallet address, allowing them to cast votes securely. Votes are then submitted through smart contracts, which automate the collection process while using homomorphic encryption and SHA-256 hashing to protect voter anonymity and data integrity. Once cast, votes are stored in a decentralized dis tributed ledger, where they are validated using a consensus mechanism such as Proofof-Stake (PoS) or Byzantine Fault Tolerance (BFT) to prevent unauthorized modifications. The system further enhances election integrity by enabling real-time vote counting through smart contracts, eliminating manual errors and reducing ma nipulation risks. The results are publicly accessible on the blockchain, ensuring full transparency and trust in the election process. Additionally, the system is designed to support large-scale elections with high transaction throughput, making it both scalable and accessible to voters worldwide. This blockchain-based voting system aims to revolutionize elections by providing a fraud-proof, transparent, and decen tralized voting process, ultimately strengthening trust and integrity in democratic systems

B. Architecture

The system architecture of the blockchain-based voting system is designed to ensure secure, transparent, and decentralized voting. At the core of the system is a web application, which serves as the primary interface for voters to interact with the platform. This web application sends HTTP requests to a web server, which acts as a mediator between

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the user and the blockchain network. The web server processes these requests and determines whether a user has an existing account. If the user does not have an account, the system generates a unique social number, blockchain address, and private key, which are securely stored in a MySQL database using JSONRPC (Remote Procedure Call) for communication. If the user already has an account, the system retrieves their blockchain address and authorizes them to interact with the smart contract for voting. The smart contract, deployed on the blockchain, automates the voting process by validating votes, preventing double voting, and ensuring anonymity. The web server commu nicates with the Web3 event emitter, which facilitates real-time interaction with the blockchain. Once a vote is cast, it is recorded on the immutable blockchain ledger, ensuring that no entity can alter or tamper with the results. The decentralized nature of the blockchain ensures that votes are transparently accessible for verifi cation while maintaining voter anonymity. This architecture significantly enhances election security, eliminates fraud, and ensures trust in the electoral process through the power of distributed ledger technology.

C. Components

Web application The web application serves as the primary interface for users to interact with the blockchain-based voting system. It allows voters to authenticate their identities, cast their votes, and receive real-time updates on the voting process. The web application communicates with the web server through HTTP requests to handle authentication and voting transactions securely. Additionally, it listens to Web3 event emitters to ensure that any blockchain-based updates, such as vote confirmations and status changes, are reflected instantly on the user interface, enhancing transparency and trust in the voting process.

Web server The web server functions as a bridge between the web application and the blockchain network, ensuring seamless communication between the frontend and backend com ponents. It processes HTTP requests from the web application, handling authen tication, user verification, and transaction requests. The server interacts with the database to check if a voter has an existing account, retrieving credentials securely. Based on the user's status, it either registers them as a new voter or enables inter action with smart contracts for casting votes. This intermediary role ensures data integrity, security, and efficient communication within the blockchainbased voting system. MySQL database The MySQL database serves as a secure repository for storing voter information, including social numbers, addresses, and private keys, ensuring data integrity and accessibility. When a user attempts to vote, the system first checks the database to verify if they have an existing account. If no account is found, the system gen erates the necessary credentials, including a unique address and private key, and securely stores them in the database. This database plays a crucial role in manag ing voter authentication and ensuring that only registered users can participate in the blockchain-based voting process. Voter Smart Contract The Voter Smart Contract is responsible for registering new voters who do not already have an account in the system. When a new user attempts to vote, the con tract verifies their registration status and, if necessary, generates a unique blockchain address and private key for them. This information is securely stored, ensuring that each voter has a distinct identity on the blockchain. By leveraging smart contracts, the system enhances security, eliminates manual intervention, and ensures trans parency in the voter registration process. Voting Smart Contract The Smart Contract for Voting is the core component that manages the voting process on the blockchain. It ensures that only authorized voters can cast their votes Dept. of CSE 12 SIMAT, Vavanoor Blockchain Based Voting

System by verifying their credentials before allowing them to participate. Once a vote is cast, it is stored immutably on the blockchain, preventing any possibility of tampering or alteration. The smart contract also emits Web3 events, enabling real-time tracking of votes and ensuring transparency in the election process. This decentralized approach enhances security, eliminates fraudulent activities, and provides an auditable voting system

VI. Methodology

Voter Authentication and Account Creation • User Authentication: The web server verifies voter details stored in the MySQLdatabase. If an existing record is found, the voter can proceed with the election process. This step ensures that only registered voters can participate and eliminates unauthorized access to the system. • Account Creation: If no account exists for the user, the voter smart contract is triggered to generate a unique blockchain address along with a secure private key. These credentials are securely stored in the database, enabling seamless authentication and ensuring that each voter has a unique digital identity on the blockchain. 3.5.2 Voter Process and Real Time Transparency • Casting a Vote: Verified voters can interact with the voting smart contract using JSON RPC. The smart contract enforces voting rules, ensuring that only eligible users can cast a vote. Once a vote is recorded, it is immutably stored on the blockchain, preventing any tampering or unauthorized modifications. • Real-time Updates: Web3 event emitters provide real-time notifications about successful voting transactions and election results. This transparency enhances trust in the electoral process by allowing users to track their votes and election outcomes instantly

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VII. Dataset

To ensure transparency, security, and immutability in electronic voting, we developed a blockchain-based voting system that records all transactions on a de centralized ledger. The system collects and stores data related to voter participa tion, vote transactions, and blockchain validation metrics. This application allows real-time vote casting, verification, and result analysis while preventing fraudulent activities such as double voting or tampering. For data analysis, key parameters were recorded in various voting scenarios, including normal voting transactions, simulated fraudulent attempts, and network delays affecting vote confirmation. The results, as shown in Table 4.1, highlight the essential metrics for assessing system efficiency and security. The maximum time required for a vote to be confirmed is determined to be under 10 seconds under optimal conditions. It is important to note that these values are preliminary and may vary based on network traffic and blockchain consensus algorithms. Additionally, vote validation data was analyzed, focusing on the number of con fSreepathy irmations required before a vote is officially counted. Any vote with less than three confirmations is flagged as unverified, ensuring that all counted votes have undergone proper blockchain validation

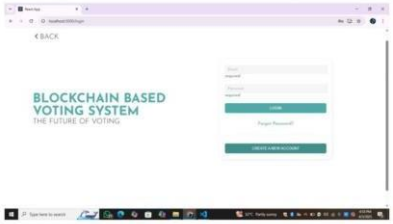

Figure 5.1: login Page

Fig. 1. Caption

Figure 5.2: :Authentication Page

Fig. 2. Caption

VIII. Results

To evaluate the performance and reliability of our system, extensive exper imentation was conducted utilizing real-world scenarios and simulated accidents. This section presents the experimental results and analyses the effectiveness of the Emergency Response Network (ERN) application in detecting and responding to emergencies. 5.1 User Login and Signup The login page of the Blockchain-Based Voting System serves as a secure en try point for users, ensuring only authenticated individuals can access the platform. It features a simple yet efficient interface with fields for email and password, both marked as required for authentication. Users can log in using their credentials, reset their password via the ”Forgot Password?” option, or create a new account through the ”Create a New Account” button. The page prioritizes security and accessibility, leveraging blockchain technology to ensure tamper-proof user authentication. With potential encryption, multi-factor authentication, and blockchain-based identity ver ification, the system guarantees secure and transparent participation in the voting process. The minimalistic but functional design enhances usability while reinforcing the integrity and reliability of the voting system.

Profile Setup

The profile setup page in the displayed React application provides a user friendly interface for managing personal account details. It features a clean and minimalistic design with a sidebar navigation menu for easy access to different sec tions, including ”Home,” ”Verify Users,” and ”Profile.” The profile section displays a circular user avatar, the user’s name (e.g., ”John”), and a ”Logout” button. There are also placeholder fields indicating where user details would be displayed or edited. The page ensures a structured layout with a responsive design, making it accessible and easy to navigate. Additionally, the copyright notice at the bottom suggests that this application belongs to ”BBVS” and is designed for use in 2025

Figure 5.3: Profile Page

Fig. 3. Caption

Registration and Verification Process

The registration and verification process in the BlockchainBased Voting Sys tem involves multiple steps to ensure security and authenticity. First, a user signs up by providing essential details such as name, email, and password. Upon success ful registration, the system notifies the user of the completion of the signup process. However, before the user can access the system, their account must be verified. The verification process is managed by an administrator who can either approve (verify) or reject (delete) the user from the system. If a user attempts to log in before be ing verified, they receive a ”Not Verified” error message, preventing

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unauthorized access. This process ensures that only legitimate users can participate, maintaining the integrity of the blockchainbased voting system.

Candidate Setup

The candidate setup page in the election web application allows users to configure candidates for an election. The interface displays a section titled ”FOR PRESIDENT” and ”ELECTION FOR PRESIDENT,” indicating that the election is for the presidential position. Users can add candidates by entering a name in the input field and clicking the ”ADD” button, which then lists the candidate along with a remove option to delete them if needed. The ”START ELECTION” button at the bottom initiates the election once all candidates have been added. This setup ensures that the user can manage candidates dynamically before commencing the voting process.

Voting And Final Process

The voting process page is designed to facilitate an election where voters can cast their votes for candidates running for a specific position. The page displays a real-time voting progress bar for each candidate, visually representing the number of votes received. Initially, all candidates have zero votes, but as users cast their votes, the progress bars fill up accordingly. Each candidate is presented with a ”VOTE” button beneath their name, allowing users to select their preferred candidate. Addi tionally, a side navigation menu provides access to different sections such as ”Polls” and ”Profile.” The interface is minimalistic and user-friendly, ensuring a smooth and transparent voting experience. The voting results dynamically update, allowing users to track the election progress until it is concluded. Ganache is a personal Ethereum blockchain simulator used for smart contract development and testing. It provides a local environment where developers can deploy, test, and debug their blockchain applications without incurring real costs. In the provided image, Ganache displays multiple Ethereum accounts with their corresponding addresses, balances, and transaction counts. The first account has conducted ten transactions, reducing its balance slightly to 99.99 ETH, while the others maintain their initial 100 ETH balances. The interface also includes informa tion such as gas price, gas limit, network ID, and an auto-mining status, ensuring seamless testing of smart contracts. By integrating Ganache with development tools like Truffle and MetaMask, developers can efficiently simulate Ethereum transactions and enhance the security and functionality of their blockchain applications.—

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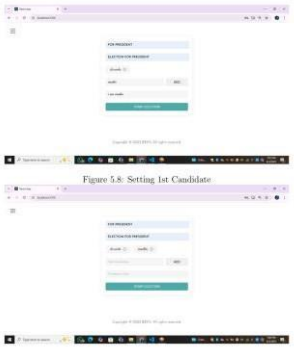

Figure 5.8: Setting 1st Candidate

Figure 5.9: Setting 2nd Candidate

Fig. 6. Caption

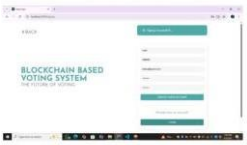

Figure 5.4: Registration Page

Figure 5.5: After Submission

Fig. 4. Caption

Figure 5.10: Created voting

Figure 5.11: voting

Fig. 7. Caption

IX. Conclusion and Future Scope

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Figure 5.6: Verification Page(Admin)

Figure 5.7: After Verification

Fig. 5. Caption