AI Driven Smart Safety and Accident-Avoidance System

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ABSTRACT

This paper addresses the escalating road safety challenges in urban environments like Delhi, where high-speed traffic,poor visibility,and human error contribute to a high incidence of accidents, exacerbated by vehicle emissions and air pollution. We present an AI-Driven Smart Road Safety and AccidentAvoidance System that leverages AI and IoT technologies to offer a cost-effective and scalable solution. The system integrates sensors (LiDAR, smoke sensors) with an ESP32 microcontroller for real-time monitoring of vehicle proximity and air quality. A lightweight Scikit-learn AI model enables proactive collision avoidance through automatic braking, LCD alerts, buzzer warnings, and Blynk notifications, while simultaneously monitoring vehicle emissions. This innovative approach enhances road safety, mitigates pollution, and offers a pathway towards smarter, safer, and greener urban transportation.

Keywords:AI-Driven Road Safety System,ESP32Microcontroller,LiDARSensor,MQ-135Smoke Sensor,Scikit-learn AI Model, Blynk IoT Platform, Real-time Collision Avoidance, Smart Accident Prevention

1. INTRODUCTION

In the bustling urban landscapes of metro cities like Delhi, road safety remains a critical challenge, withaccidents caused by high-speed traffic, poor visibility, and human error claiming countless lives annually. Compounding this issue, vehicle emissions contribute significantly to air pollution, further impairing visibility and posing environmental and health risks. To address these pressing concerns, we present an AI-Driven Smart Road Safety and Accident Avoidance System, a cutting-edge solution that leverages Artificial Intelligence (AI) and Internet of Things (IoT) technologies to revolutionize urban transportation. Our system integrates advanced sensors, such as LiDAR and smoke sensors, with the powerful ESP32 microcontroller to enable real-time monitoring of vehicle proximity and air quality. By detecting potential collisions and triggering automatic braking or alerts through buzzers and LCD displays, it ensures swift accident prevention. Simultaneously, the system monitors vehicle emissions, promoting environmental awareness and sustainability. Designed to be cost- effective and scalable, this solution is adaptable to all vehicles, offering a practical and impactful approach to enhancing road safety and reducing pollution in urban areas. This project aims to create a safer, smarter, and greener future for transportation by combining innovative technology with a commitment to saving lives and protecting the environment.

1.1 OBJECTIVES

- EnhanceRoadSafety: Preventaccidentswithreal-timecollisiondetectionusingLiDARandESP32,and enable automatic braking.
- MonitorVehicleEmissions:Detectpollutants(CO,particulatematter)usingasmokesensorandalert drivers.
- EnsureCost-EffectivenessandScalability: Uselow-costcomponents(ESP32,standardsensors)anda modular design.
- PromoteEnvironmentalAwareness:Encourageemissionreductionthroughdriveralerts,improvingair quality.

2. LITERATUREREVIEW

The Internet of Things (IoT) has become a transformative technology for vehicle safety and environmental monitoring, enabling real-time data collection and emergency response. This study emphasizes the importance of integrating sensors, GPS, and cloud computing to enhance road safety and reduce pollution.

Tasgaonkaretal.(2023)developedan**IoT-basedaccidentdetectionframework**using**ESP32,accelerometers,and GPS** to identify collisions and alert emergency services via cloud-based Google Maps API, significantly reducing response delays [1]. Asha et al. (2022) proposed an **intelligent air pollution tracker** using a **smoke sensor and GPS module** to monitor vehicular emissions in real-time, enabling authorities to take action against high-polluting vehicles [2].
Khan et al. (2022) introduced an **IoT-based air quality monitoring system** that integrates **gas sensors with a mobile application**, allowing users to track emission levels and receive alerts, thereby improving environmental awareness [3]. Tahemeen & Patil (2024) designed an **accident detection and intimation system** using an **accelerometer and ESP32 microcontroller**, which sends location alerts to emergency contacts via messaging platforms, improving accident response times [4].Pandithurai et al. (2023) explored an **IoT-based vehicle pollution monitoring system** that flags vehicles exceedingemissionstandardsandnotifiesauthoritiesforcorrective action,contributingtobetterairqualitymanagement [5]. Khobragade & Salve (2021) developed a **pollution monitoring and control system** that uses **gas sensors to trigger automatedresponses**,such asdriveralertsor engineadjustments,to reduceemissions[6].Talekaretal.(2024) proposed an **IoT-based accident alert system** that detects crashes using **impact sensors** and transmits location data to emergency services, demonstrating effectiveness in simulated scenarios [7]. Talukder et al. (2022) implemented a **collision detection and prevention system** using **VANET and Vehicle-to-Vehicle (V2V) communication**, where vehicles share real-time position and speed data to avoid accidents [8].Ballamajalu et al. (2018) introduced **SATVAM**, an **IoT network for air quality monitoring**, which collects and analyzes pollution data across multiple locations to support environmental policies [9]. Park et al. (2021) developed **GeoAir**, a **portable, GPS-enabled air pollution sensor**, designed for public use intracking personal exposure to pollutants [10].

Thedisadvantagesoftheexistingmethods:

- HighFalsePositivesinAccident Detection
- LimitedReal-TimeProcessingCapabilities
- SensorAccuracyand Environmental Interference
- ScalabilityandCostBarriers

- PrivacyandDataSecurity Risks
- HighFalsePositivesinAccident Detection

Toovercomethespeechrecognitionsystem,weshouldkeepthemicrophoneclosetotheuser.

3. PROPOSEDWORK

The proposed IoT-based system integrates **real-time sensor monitoring, AI-driven risk prediction, and automated collision avoidance** to enhance road safety and environmental awareness. At its core, the **ESP32 microcontroller** processes data from multiple sensors, including a **TF-Luna LiDAR** for precise distance measurement (0.2 m to 8 m) and an **MQ-135 smoke sensor** for detecting harmful pollutants (CO, NOx, 10-1000 ppm). The system employs a **hybrid sensor approach**, combining LiDAR and ultrasonic sensors (HC-SR04) for robust obstacle detection in diverse conditions. When an obstacle is detected within a critical range (50 cm for LiDAR, 20 cm for ultrasonic), the system triggers **audible (buzzer) and visual (LCD) alerts**, while the ESP32 activates **automatic braking via an L298N motor driver** to prevent collisions. Simultaneously, if pollutantlevels exceed safe thresholds (300 ppm), the system alerts the driver and logs data for further analysis, promoting eco-friendly driving behavior

To improve predictive capabilities, a **lightweight machine learning model** (e.g., decision tree or random forest)isdeployedontheESP32,trainedusing**Scikit-learn**andoptimizedforembeddedsystems via **MicroPython or ONNX conversion**. This AI model analyzes real-time sensor inputs to classify risk levels (e.g., "safe," "warning," "critical"), enabling proactive responses such as early warnings or emergency braking. The system also leverages **Blynk IoT** for remote monitoring, transmitting sensor data to a mobile app and cloud dashboard. This allows drivers and authorities to access real-time updates on road conditionsand pollutionlevels, facilitating timely interventions. The integration of **Wi-Fi (ESP32) and optional ESP-01 modules** ensures seamless connectivity, while a **12V battery and 7805 voltage regulator** provide stable power for continuous operation in urban environments.

The proposed methodology addresses key challenges in existing systems, such as **false alarms, network dependency, and sensor limitations**, by combining **multi-sensor fusion, edge AI processing, and cloud-based alerts**.The modular hardware design,featuringan **ABS plasticenclosure and breadboard prototyping**, ensures durability and scalability for real-world deployment. By unifying **accident prevention, pollution monitoring, and IoT connectivity**, this system offers a comprehensive solution for improving road safety and air quality in congested urban areas like Delhi, while laying the groundwork for future **Vehicle-to-Vehicle (V2V) and smart .**

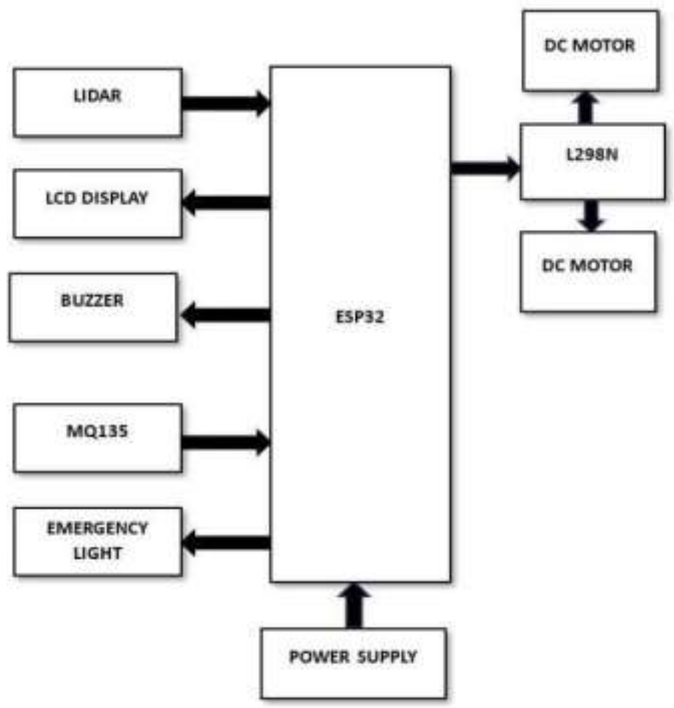

Fig1.BlockDiagram

3.1 HARDWAREREQUIREMENT

1. ESP32Microcontroller

The ESP32microcontroller is the heart of the AI-Driven SmartRoad Safety and Accident Avoidance System, serving as the central processing unit for data collection, processing, and actuation. This versatile, low-cost module features a dual-core Xtensa LX6 processor running at 240 MHz, enabling efficient handling of sensor dataandAIcomputations.In thesystem,theESP32interfaceswithsensorsliketheLiDAR(TF-Luna),smoke sensor (MQ-135), and ultrasonic sensor (HC-SR04) to gather real-time data on obstacle distances and air quality. It runs a lightweight AI model, developed using Scikit-learn, to predict collision and pollution risks, triggering appropriate responses such as alerts or automatic braking. The ESP32 controls actuators, includinga DC motor for braking and a buzzer for audible warnings, via its 36 GPIO pins, which support multiple interfaces (UART, I2C, SPI, ADC).

Fig 1:ESP32Microcontroller

2. SmokeSensor

The MQ-135 smoke sensor monitors air pollutants like CO, NOx, and ammonia, helping control urban pollution.
ItusesaSnO_2sensingelementtogenerateanalogsignalsbasedongaslevels,whichtheESP32convertstodigital data.
When pollution exceeds 300 ppm, the system triggers LCD alerts, buzzers, and Blynk app notifications.
Compactandcost-effective,itfitseasilynearavehicle'sexhaustorcabinintake.IntegratedwithIoTfeatures,it enables real-time, remote pollution monitoring for smart city applications.

Fig2:Smoke Sensor

3. LCDDisplay

AnLCDscreencan displayusefulinformationtotheusersuchasthecurrentcommand,systemstatusorerror messages. This feedback helps users understand the system's operation and troubleshoot any issues. Some systems incorporate audible alerts or LEDs to indicate status, providing feedback. Fig 3. Shows the LCD Display 2 x 16.

Fig3.LCD Display2x 16

4. ServoMotors

The Servo Motors is mainly used for the robotic arm's precise angular movements. The servo motor driver allows for a multi axis control and complex movements. The Arduino send a signal to control the angle and speedoftheservos,enablingprecisecontroloverthearm'smovements. Fig4.showstheServoMotorSG90.

Fig4. ServoMotorSG90

5. UltrasonicSensor

The HC-SR04 ultrasonic sensor provides accurate short-range obstacle detection up to 400 cm, with ±3 mm precision, operating at 40 kHz. It complements LiDAR in the AI-Driven Smart Road Safety System by detecting close objects, especially within 20 cm. When triggered, it activates alerts like LCD warnings, buzzer sounds, and DC motor braking. With low power usage (~15 mA) and easy integration via digital pins, it suits energy-efficient ESP32-based systems. Its compact size and affordability support hybrid detection and scalability in dense urban environments like Delhi.

Fig5:Ultrasonic Sensor

6. DC Motor

Tomanageheaviermovementssuchasliftingorrotatinglargersectionsofthearm,DCmotorsareutilized. These motors offer increased torque, crucial for handling heavier loads. Motor drivers regulate thespeed and direction of the DC motors, following commands from the Arduino to ensure smooth and dependable operation. Fig 6 shows the DC Motor .

Fig6: DCMotor

7. LiDAR(LightDetectionandRanging)

LiDAR is a remote sensing technology that uses laser pulses to measure distances with high precision. It calculates distance by measuring the time taken for the laser light to reflect back from a surface. When integrated with GPS and IMUs, it creates detailed 3D maps of surroundings. LiDAR is widely used in autonomous vehicles for real-time object detection and collision avoidance. Unlike cameras, it works well in low-light conditions and can provide a 360-degree view.

Fig7 :LiDAR

8. BUZZER

The active piezo buzzer provides audible alerts (~2.5 kHz) for collision or pollution warnings, triggered by sensor thresholds likeobstacledistance orCOlevels. Controlled by theESP32via asingle GPIO pin, it consumes minimal power (~15 mA) and operates on 3.3V–5V DC. Its compact size (~12 mm) allows easy placement near thedriver,complementingvisualLCDalerts.Thebuzzer'sloudtoneensuresimmediateattention,crucialinurban settings like Delhi. Its low cost, simple integration, and reliable performance make it vital for real-time safety and environmental alerts.

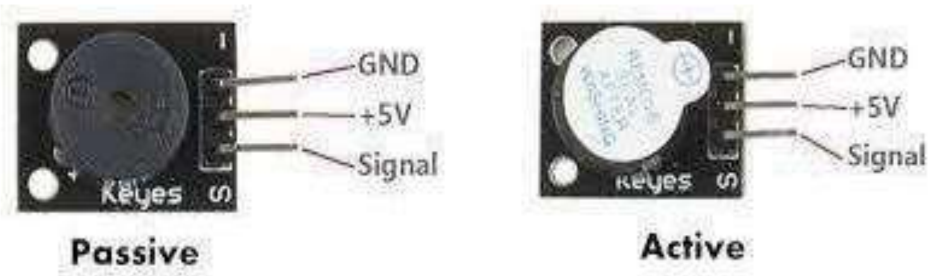

Fig8 :Buzzer

WORKINGPRINCIPLE

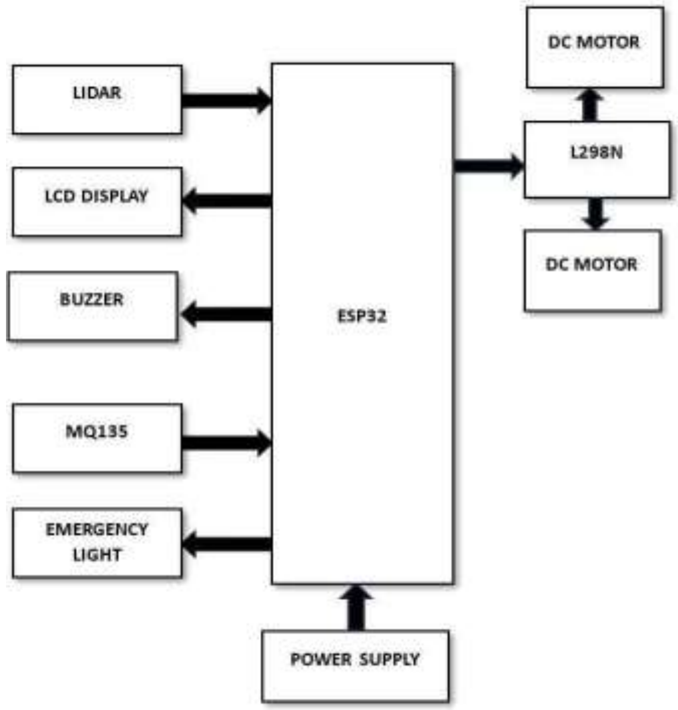

Fig9:WorkflowDiagram SYSTEM COMPONENTS ANDFUNCTIONALITY

- ESP32Microcontroller–Actsasthecentralprocessingunit,managingdata from the sensors and controlling the alert mechanisms.
- SmokeSensor–Detectsexcessivevehiclesmokeemissionsandalertsthe driver to take necessary action to reduce pollution.
- LiDARSensor–Continuouslymonitorsthedistanceofapproachingor nearby vehicles, helping in collision avoidance.
- DCMotorandMotorDriver–Canbeusedforautomaticbrakingtoprevent accidents when an obstacle is detected.
- LCDDisplay–Providesreal-timealertsandwarningsrelatedtoairpollution levels and nearby obstacles.
- Buzzer–Soundsanalarmtoalertthedriverwhencriticalpollutionlevelsor collision risks are detected.
- HowItWorks
- Thesmokesensordetectshighpollutionlevelsandtriggersanalertif emissions exceed a predefined threshold.

➢ TheLiDARsensorcontinuouslyscansfornearbyvehiclesorobstaclesand warns the driver if an imminent collision is detected.

➢ Ifahigh-risksituationoccurs,thebuzzerproducesasoundalarm,andthe LCD display provides a visual warning.

➢ TheDCmotorandmotordrivercanbeprogrammedtoapplyautomatic braking in case of an emergency to prevent collisions.

➢ Thesystemoperatesinreal-time,ensuringinstantresponsestohazardous conditions on the road.

SystematicDiagram

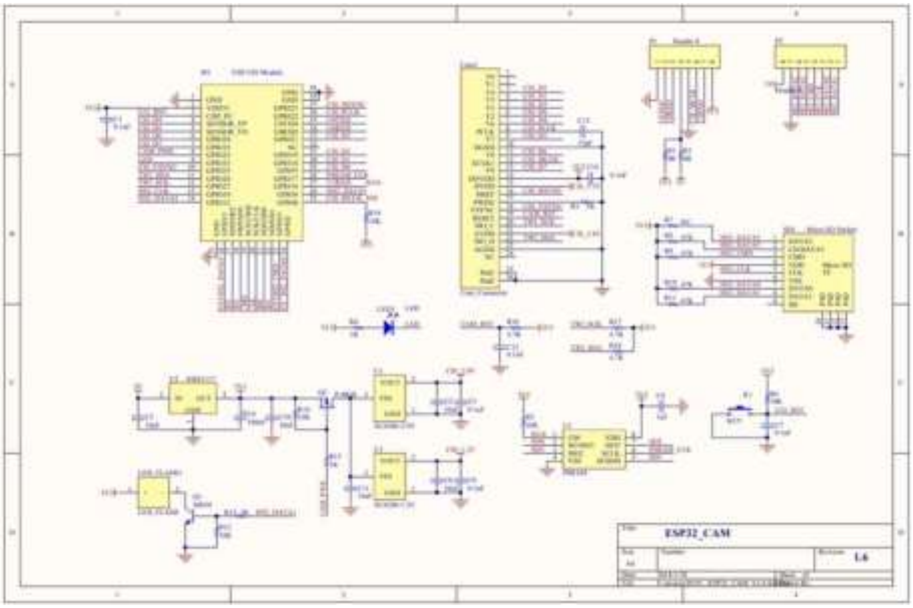

Figure10:SystematicDiagram

ESP32 Features&Specifications

➢ ThismodulesupportsWiFi andBluetooth.

➢ IthasanOnboardTFcardslotthatsupports upto4GTFcardsusedfordata storage

➢ ItsupportsWi-Fivideomonitoring&image upload.

➢ Itsupportsdifferentsleepmodeswith6mAlowadeepsleepcurrent.

➢ Thecontrolinterfacecanbeaccessibleeasilythroughapinheader.

BLynk

Blynk is a comprehensive software suite that enables the prototyping, deployment, and remote management of connected electronic devices at any scale.

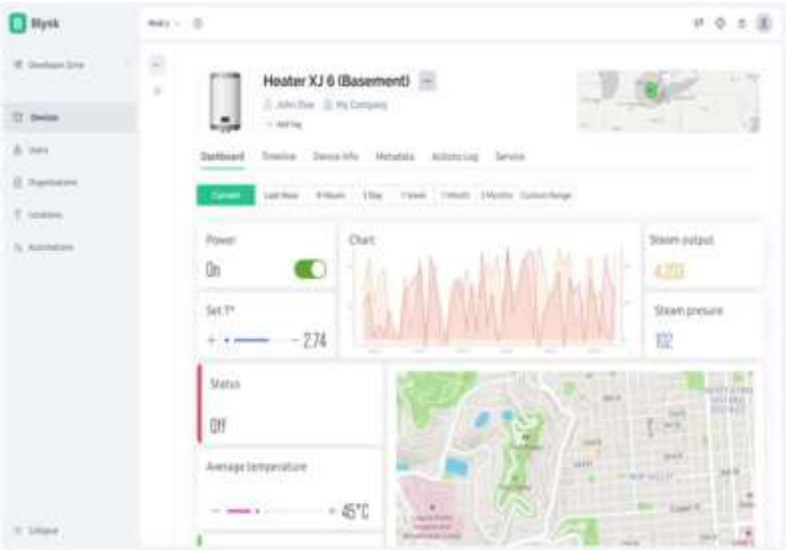

Fig11:BLynk

BLynkApps

Fig12: BLynk

Blynk.AppsisaversatilenativeiOSandAndroidmobileapplicationthatservesthese major functions:

- Remotemonitoringandcontrolofconnecteddevicesthatworkwith Blynk platform.
- Configurationofmobile UI during prototypingand production stages.
- Automationofconnecteddeviceoperations.

BLynkR

Fig13:BLynK

RESULTS

Theproposedmodelofour projectisdisplayedbelow. Fig14.Showstheproposedmodel

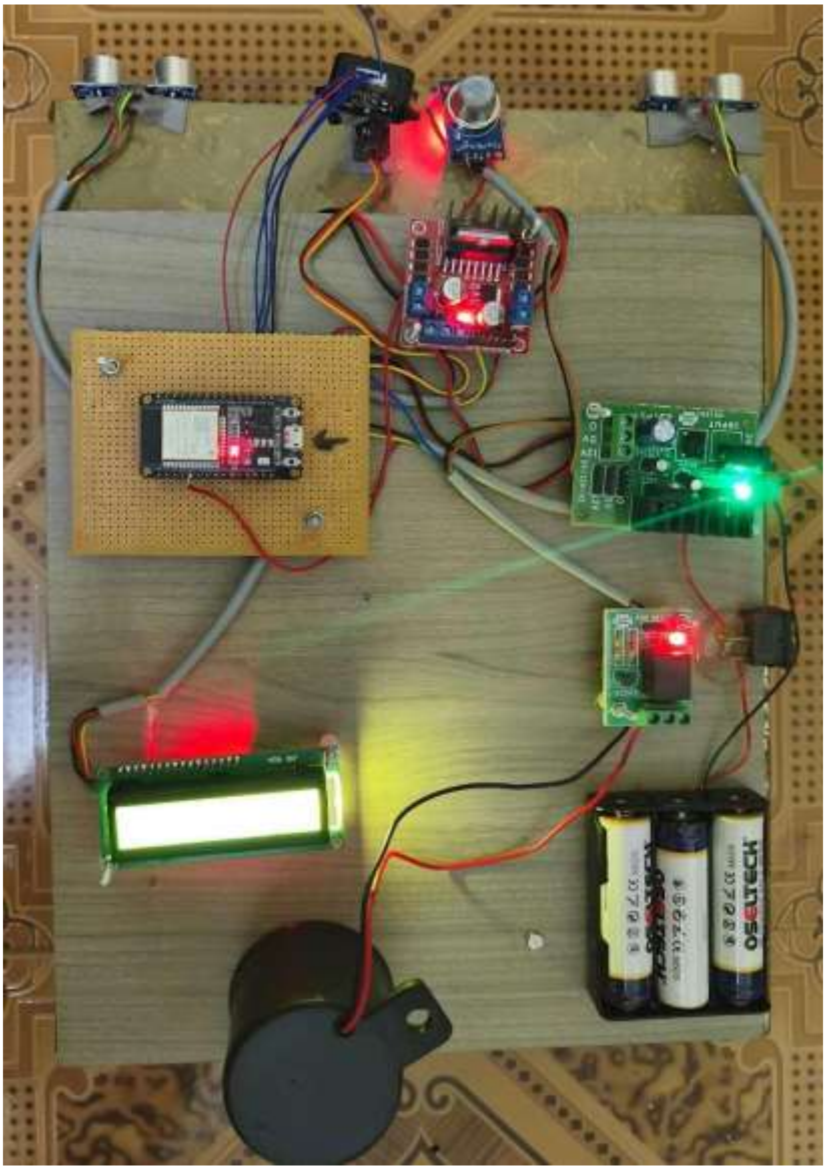

Fig14. Proposedmodel

Thebelowfigureshowstheworkingofourprototypewhichidentifiestheobject,vehicle beyond the fogg or smoke.

Fig15. Commanddisplaying inLCD

Afterthatourmodelwillpicktheobjectandplacetheobject.Fig16.showsanobjectispicked.

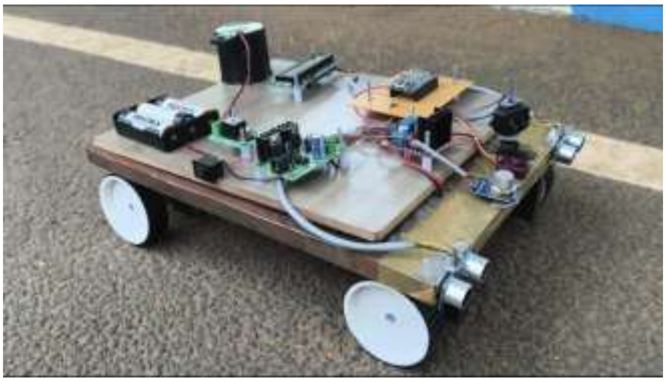

Fig16. object

Fig17.Anobjectisdetected

Fig18:AltrtingNotification

In this below figure we have the user interface which receives the live data from the Blynk app as well as from the LCD display and in case of any obstacles or vehicle detection it sends an alert notification to the user.

4. DISCUSSSION

The proposed AI-Driven Smart Road Safety and Accident-Avoidance System addresses two pressing urban challenges: increasing road accidents and deteriorating air quality. Through the integration of LiDAR and ultrasonic sensors, the system ensures precise and redundant obstacle detection, crucial in high-traffic environments where human reaction time may be inadequate. The use of the MQ-135 sensor for pollution monitoring adds an environmental dimension, alerting drivers to harmful emission levels and encouraging more responsible driving behaviors.

The real-time response enabled by the ESP32 microcontroller, in coordination with actuators like the DC motor and buzzer, enhances the system's capability to prevent accidents rather than merely respond to them.

Integration with the Blynk IoT platform demonstrates the potential for remote monitoring and future smart city applications, allowing authorities or users to access live data and alerts.

While the current implementation demonstrates functional success in prototype testing, challenges such as sensor calibration,real-timedataprocessingunder dynamicconditions,andweather-relatedinterferencemayaffectlong- term deployment. Nevertheless, the system's modularity and low-cost design make it highly scalable and adaptable. With enhancements like GPS, vehicle-to-vehicle (V2V) communication, and more advanced AI models, the system holds promise for future development in intelligent transportation infrastructure.

5. CONCLUSION

The AI-Driven Smart Road Safety and Accident Avoidance System represents a transformative approach to addressing urban traffic safety and environmental challenges. By integrating cost-effective hardware, such as the ESP32 microcontroller, TF-Luna LiDAR, MQ-135 smoke sensor, and HC-SR04 ultrasonic sensor, with advanced AI and IoT technologies, the system delivers real-time collision avoidance and air pollution monitoring. The lightweight Scikit-learn AI model predicts risks with high accuracy, triggering automatic braking, LCD alerts, buzzer warnings, and Blynk IoT notifications, ensuringproactivesafetymeasures.Itsaffordability, withaprototype costunder$50,andscalabilitymake it accessible for widespread adoption, particularly in developing countries like India. The system's adaptability tourbanconditions,such as Delhi'sdense traffic, fog, andsmog, enhances itseffectivenessin reducing accidents and promoting eco-friendly driving. The seamless integration of open-source software, including Arduino IDE, MicroPython, and Python, ensures robust performance and ease of development. Future enhancements, such as vehicle- to-vehicle communication and smart city integration, promise to amplify its impact. By combining safety and environmental monitoring, the system addresses criticalurban challenges, offering a scalable, innovative solution that improves road safety, reduces pollution exposure, and paves the way for smarter, safer cities.

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