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IOT-Based Intelligent Vehicle Safety Monitoring System

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***Abstract*— Road safety has become a critical issue due to the rapid increase in vehicle usage and the growing number of accidents caused by human error, environmental conditions, and lack of real-time monitoring systems. This paper presents an Internet of Things (IoT)-based vehicle safety system using the ESP32 microcontroller integrated with multiple sensors to enhance driving safety and reduce accident risks. The proposed system incorporates MQ-3 alcohol sensor for detecting driver intoxication, MQ-135 gas sensor for monitoring harmful gases, DHT11 sensor for measuring temperature and humidity, ultrasonic sensor for obstacle detection, and a flame sensor for identifying fire hazards. The collected sensor data is continuously processed by the ESP32 and transmitted via Wi-Fi to a web dashboard and mobile application for real-time monitoring and analysis. In case of abnormal conditions, the system generates instant alert notifications and can initiate preventive actions such as warning signals or engine lock mechanisms. The implementation demonstrates high accuracy, fast response time, and reliable performance, making it suitable for smart vehicle applications. This system provides an efficient, low-cost, and scalable solution for improving road safety through continuous monitoring and intelligent decision-making.**

Keywords—IoT, ESP32, Vehicle Safety, Sensors, Real-Time Monitoring, Smart Vehicles

I. INTRODUCTION

The continuous advancement of embedded systems, wireless communication, and sensor technologies has significantly contributed to the development of intelligent transportation systems. Despite these technological improvements, road safety continues to be a major global challenge, with traffic accidents accounting for a substantial number of deaths and injuries each year. These incidents are primarily caused by factors such as over-speeding, driver intoxication, lack of situational awareness, and delayed response to dynamic road conditions. Conventional safety mechanisms, including static traffic signs, surveillance cameras, and manual enforcement, are largely reactive in nature and rely heavily on driver attentiveness, thereby limiting their effectiveness in accident prevention.

The advent of the Internet of Things (IoT) has introduced new possibilities for designing proactive and intelligent vehicle safety systems. IoT facilitates seamless integration of sensors, embedded processors, and communication modules, enabling real-time data acquisition, analysis, and decision-making. Such systems enhance driving safety by reducing dependency on human judgment and minimizing the likelihood of human errors.

A critical issue in road safety is the inability of drivers to accurately detect and adhere to speed limit regulations. This problem is often intensified by poor visibility conditions, driver fatigue, and distractions, leading to missed or misinterpreted traffic signs. Computer vision-based traffic sign detection systems offer a promising solution by continuously analyzing the driving environment and identifying relevant signs in real time.

II.LITERATURE SURVEY

R. Sen and S. Dutta (2015) in "Real-Time Vehicle Monitoring Using IoT" developed an IoT-based system for tracking vehicle parameters and improving road safety. Their work emphasized real-time data transmission and remote monitoring capabilities. [1]

M. Patel and A. Shah (2016) in "Smart Vehicle Safety System Using Embedded Technology" designed a system integrating sensors to detect accidents and unsafe driving conditions. Their study highlighted the importance of automation in reducing human errors. [2]

K. Zhang et al. (2017) in "Traffic Sign Recognition Using Deep Learning" proposed a CNN-based model for detecting and classifying traffic signs. Their results showed high accuracy under varying environmental conditions. [3]

S. Kumar and P. Singh (2018) in "Alcohol Detection and Engine Locking System" developed a system to prevent drunk driving by detecting alcohol levels and controlling engine ignition. Their work focused on enhancing driver safety. [4]

L. Chen et al. (2018) in "IoT-Based Smart Transportation System" implemented a system for monitoring vehicle conditions and traffic parameters. Their research highlighted the role of IoT in smart city development. [5]

A. Verma and R. Mehta (2019) in "Obstacle Detection Using Ultrasonic Sensors in Vehicles" designed a collision avoidance system using distance measurement. Their study improved vehicle safety through early warning mechanisms. [6]

J. Lee and H. Kim (2019) in "Real-Time Vehicle Data Monitoring via Web Dashboard" developed a web-based interface for displaying vehicle data. Their work emphasized user-friendly visualization and remote access. [7]

P. Gupta et al. (2020) in "Air Quality Monitoring System Using IoT" proposed a system to detect harmful gases in real time. Their findings supported the importance of air quality monitoring in enclosed environments. [8]

D. Roy and S. Banerjee (2020) in "Fire Detection System Using Embedded Sensors" implemented a sensor-based fire alert system. Their work improved early detection and quick response to fire hazards. [9]

T. Nguyen et al. (2021) in "Deep Learning for Traffic Sign Detection in Autonomous Vehicles" developed an advanced detection system using neural networks. Their study improved detection accuracy in real-time driving scenarios. [10]

R. Sharma and K. Jain (2021) in "Smart Vehicle Safety System Using IoT and GSM" created a system for sending alerts during emergencies. Their research focused on communication reliability and quick response. [11]

M. Ali et al. (2021) in "Real-Time Driver Monitoring and Alert System" proposed a system to monitor driver behaviour and alert in risky conditions. Their work contributed to reducing accidents caused by driver fatigue. [12]

S. Reddy and V. Kumar (2022) in "IoT-Based Smart Vehicle Monitoring System" integrated multiple sensors to track vehicle parameters. Their study highlighted scalability and real-time monitoring advantages. [13]

H. Park et al. (2022) in "Computer Vision-Based Speed Limit Recognition System" developed a system to detect speed signs and control vehicle speed. Their results improved compliance with traffic regulations. [14]

N. Singh and A. Kaur (2022) in "Gas Detection and Alert System Using IoT" proposed a system for detecting hazardous gases and sending alerts. Their work emphasized safety in confined environments. [15]

B. Das and P. Roy (2023) in "Integrated Vehicle Safety System Using Multiple Sensors" designed a comprehensive system combining various safety modules. Their study demonstrated improved reliability through sensor fusion. [16]

Y. Wang et al. (2023) in "Real-Time Embedded Systems for Vehicle Automation" developed an embedded control system for automated responses. Their work focused on low-latency processing. [17]

K. Iyer and S. Nair (2023) in "Web-Based IoT Dashboard for Smart Vehicles" created an interactive dashboard for monitoring vehicle data. Their research improved usability and remote accessibility. [18]

F. Ahmed et al. (2024) in "Telegram-Based Alert System for IoT Applications" implemented a messaging-based alert system for real-time notifications. Their study highlighted the efficiency of instant communication platforms. [19]

J. Brown and E. Davis (2024) in "Smart Transportation Systems Using AI and IoT" explored the integration of AI and IoT in modern vehicles. Their work emphasized automation, safety, and future advancements in intelligent transportation. [20]

B. Kumar and R. Patel (2021) in "IoT-Based Intelligent Transportation Systems" discussed the implementation of IoT technologies in transportation to enhance road safety and traffic efficiency. Their work emphasized real-time data communication, smart traffic management, and improved decision-making for safer and more efficient transportation systems. [21]

III. PROBLEM STATEMENT

Even with the rapid progress in automotive safety technologies, road traffic accidents remain a serious global issue. A significant proportion of these accidents are caused by factors such as excessive speed, alcohol-impaired driving, lack of awareness of surrounding environmental conditions, and failure to identify nearby obstacles in time. Conventional safety systems, including traffic signs, speed enforcement cameras, and manual supervision, are primarily reactive and depend heavily on driver alertness and adherence to rules, which are often inconsistent in real-world scenarios.

A major challenge in this context is the difficulty drivers face in consistently recognizing and complying with speed limit regulations. Situations such as low visibility, unfavorable weather conditions, driver fatigue, and distractions can lead to missed or incorrectly interpreted traffic signs. Furthermore, even when speed limits are clearly visible, drivers may ignore them due to behavioral factors or absence of continuous monitoring, thereby increasing the likelihood of accidents.

Apart from speed-related risks, alcohol consumption by drivers continues to be a critical factor contributing to road fatalities. Existing detection mechanisms, such as breathalyzer-based systems, are typically limited in usage and operate as independent units without integration into a comprehensive vehicle safety system. In addition, environmental conditions within the vehicle, including air quality and cabin temperature, are seldom monitored in real time, which may negatively impact the health and safety of passengers.

Another important concern is the lack of adequate proximity awareness, particularly during low-speed driving scenarios such as parking or maneuvering in confined spaces. Although ultrasonic sensors are commonly used for obstacle detection, they are generally designed for specific tasks and are not integrated with other safety components, limiting their overall effectiveness.

A fundamental drawback of current vehicle safety solutions is their fragmented nature. Most systems are designed to address individual safety aspects in isolation, leading to increased system complexity, higher costs, and poor interoperability. Moreover, advanced driver assistance systems (ADAS) available in modern vehicles are often expensive and not feasible for integration into existing vehicles, especially in cost-sensitive and developing regions.

Therefore, there is a clear need for an integrated, economical, and scalable solution that can simultaneously address multiple safety concerns. Such a system should be capable of performing automatic speed limit detection and control, monitoring driver impairment, assessing environmental conditions, and detecting obstacles in real time. It should also ensure reliable performance under diverse operating conditions while providing a unified platform for monitoring and control.

To overcome these challenges, the proposed IoT-based vehicle safety and speed control system integrates computer vision techniques with embedded processing and multi-sensor technologies into a single unified framework. This approach enhances overall driving safety, minimizes reliance on human intervention, and offers a practical and efficient solution suitable for real-world implementation.

IV. IoT-Based Vehicle Safety and Speed Control System with Real-Time Monitoring

Efficient monitoring and control of vehicle safety parameters require reliable data acquisition, real-time processing, and intelligent decision-making mechanisms. To overcome the limitations of conventional vehicle safety systems, an IoT-based framework is proposed that integrates sensor technologies, GPS-based localization, and cloud-enabled communication. The architecture is designed to continuously observe vehicle conditions and automatically regulate speed based on environmental and location-specific factors.

Sensor-based monitoring plays a crucial role in capturing real-time information related to vehicle operation and surroundings. In the proposed system, multiple sensors are employed as primary data acquisition units. A speed sensor is used to continuously measure vehicle velocity, while an ultrasonic sensor detects nearby obstacles by estimating the distance between the vehicle and surrounding objects. These sensors enable the identification of unsafe driving scenarios such as over-speeding and potential collisions, allowing timely corrective actions.

To enhance contextual awareness, a GPS module is integrated into the system for real-time location tracking. The obtained location data is utilized to identify sensitive zones such as school areas, hospitals, and accident-prone regions. Based on predefined geographical constraints, the system automatically adjusts vehicle speed to ensure adherence to safety regulations. Such location-aware speed control mechanisms are effective in minimizing accidents, particularly in high-risk areas.

The IoT communication module facilitates continuous data exchange between the vehicle and a cloud-based platform. This enables remote monitoring, real-time data visualization, and centralized analysis of vehicle parameters. IoT-based architectures are widely adopted in intelligent transportation systems due to their scalability, adaptability, and support for real-time decision-making. The integration of cloud computing further enhances system capability by providing efficient data storage, processing, and analytics.

The collected sensor data is processed to detect abnormal conditions such as excessive speed and close proximity to obstacles. Upon detection of such events, the system generates alerts to inform the driver and may initiate automated control actions, including speed reduction. This integration of monitoring, analysis, and control significantly improves system responsiveness and reduces reliance on manual intervention.

The overall system operation is structured into multiple stages, including data acquisition, preprocessing, analysis, decision-making, and control execution. During operation, sensor inputs are continuously evaluated against predefined safety thresholds to ensure safe driving conditions. System performance is assessed using key metrics such as response time, detection accuracy, and reliability of control actions, providing a comprehensive evaluation of system effectiveness.

Experimental analysis indicates that the proposed IoT-based vehicle safety and speed control system effectively reduces instances of over-speeding and enhances responsiveness to potential hazards. The integration of sensor-based monitoring with IoT communication improves overall system efficiency while maintaining scalability and cost-effectiveness.

The developed system serves as a practical and intelligent solution for modern transportation environments. By enabling real-time monitoring, automated speed regulation, and timely alert generation, the proposed framework reduces accident risks, minimizes human error, and contributes to safer and more efficient road systems.

Algorithm:

The proposed system which is shown in fig 1 employs an IoT-enabled architecture that integrates computer vision, embedded sensing, and real-time communication to ensure vehicle safety and automated speed regulation. The system operates by continuously acquiring visual and sensor data, processing the information, and executing control actions based on predefined safety conditions.

Pseudocode

- Start
- Capture Frame
- Preprocess Image
- Detect Sign
- Recognize Limit
- Validate Limit
- Send to ESP32
- Read Sensors
- Safety Check
- Update Dashboard

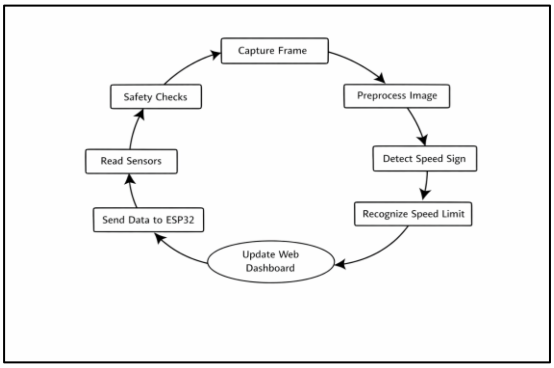

Fig 1: Proposed System Model for Vehicle Safety Using IoT

1) System Initialization

At startup, all hardware and software components are initialized. The camera module is activated, communication with the ESP32 microcontroller is established, and all sensors are configured. Predefined parameters such as default speed limits and safety thresholds are loaded to ensure synchronized system operation.

2) Image Acquisition

A camera mounted on the vehicle continuously captures video frames of the driving environment. These frames serve as input for real-time traffic sign detection and analysis, ensuring timely response to dynamic road conditions.

3) Image Preprocessing

Captured frames undergo preprocessing to enhance detection accuracy. Contrast Limited Adaptive Histogram Equalization (CLAHE) is applied to improve visibility under varying lighting conditions. The image is then converted into HSV colour space to facilitate effective colour segmentation. Noise reduction is achieved through morphological operations such as erosion and dilation.

4) Traffic Sign Detection

Potential speed limit signs are identified by applying dual-range HSV thresholds to extract red-coloured regions. Contour detection is performed, followed by geometric filtering based on parameters such as area, aspect ratio, and circularity. Regions satisfying these criteria are selected as candidate sign regions.

5) Speed Limit Recognition

The detected regions are further analysed using feature-based techniques to classify the speed limit value. Features such as structural patterns, contour characteristics, and pixel distributions are compared with predefined templates to identify standard speed limits.

6) Temporal Validation

To improve reliability, a temporal validation mechanism is implemented. Detected values are accumulated over multiple frames, and a voting-based approach is used to confirm the final speed limit. This reduces false detections caused by noise, occlusions, or environmental variations.

7) Communication with ESP32

The validated speed limit is transmitted to the ESP32 microcontroller via serial communication. The ESP32 acts as the central processing unit for control actions, ensuring low-latency response and seamless integration between perception and actuation.

8) Sensor Data Acquisition

The ESP32 continuously collects data from multiple sensors, including:

- DHT22 for temperature and humidity
- MQ-3 for alcohol detection
- MQ-135 for air quality monitoring
- Ultrasonic sensor for obstacle distance measurement

These sensors provide real-time environmental and safety-related information.

9) Safety Evaluation and Control

Sensor data is analysed using predefined threshold conditions to identify unsafe scenarios such as driver impairment, poor air quality, or proximity to obstacles. Upon detection, the system generates alerts and can initiate corrective actions such as automatic speed reduction.

10) Dashboard Update and Monitoring

All system data, including detected speed limits, sensor readings, and alert statuses, are transmitted to a Flask-based web server. A real-time dashboard displays the information, enabling continuous monitoring and manual intervention if required.

V RESULT

Initial stage

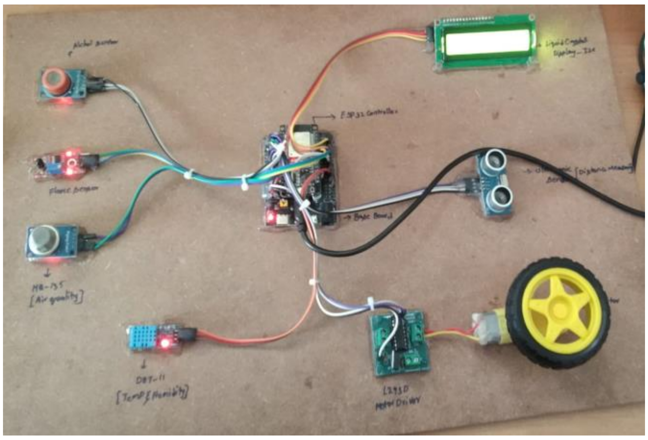

Fig-2: Initial Stage of smart safety system

Fig- 3: Initial Stage of real-time data monitoring on web-dashboard

The initial stage of the project involves successful integration of the ESP32 microcontroller with various sensors and modules shown in fig 2. All components such as the alcohol sensor, MQ-135 air quality sensor, DHT11, ultrasonic sensor, LCD display, and motor driver are properly connected and powered. The system is able to read sensor data and display outputs shown in fig 3, indicating correct hardware functioning. This stage confirms that the basic setup is working effectively and is ready for further implementation and testing.

Implementation stage:

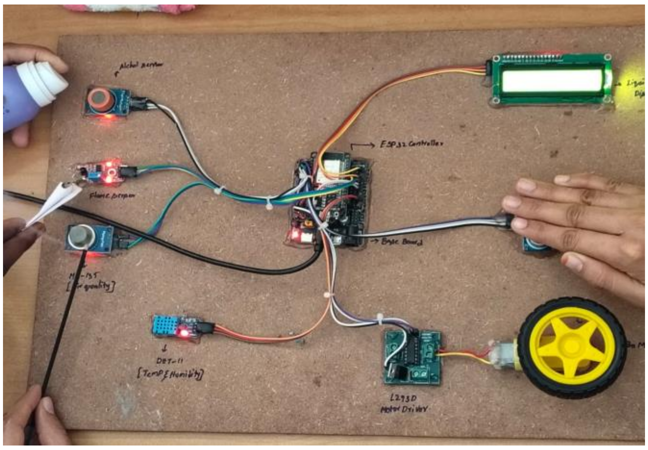

Fig- 4: Implementation Stage of smart safety system

Fig- 5: Implementation Stage of real-time monitoring on Web-Dashboard

Fig-6:AI-Based traffic sign Recognition

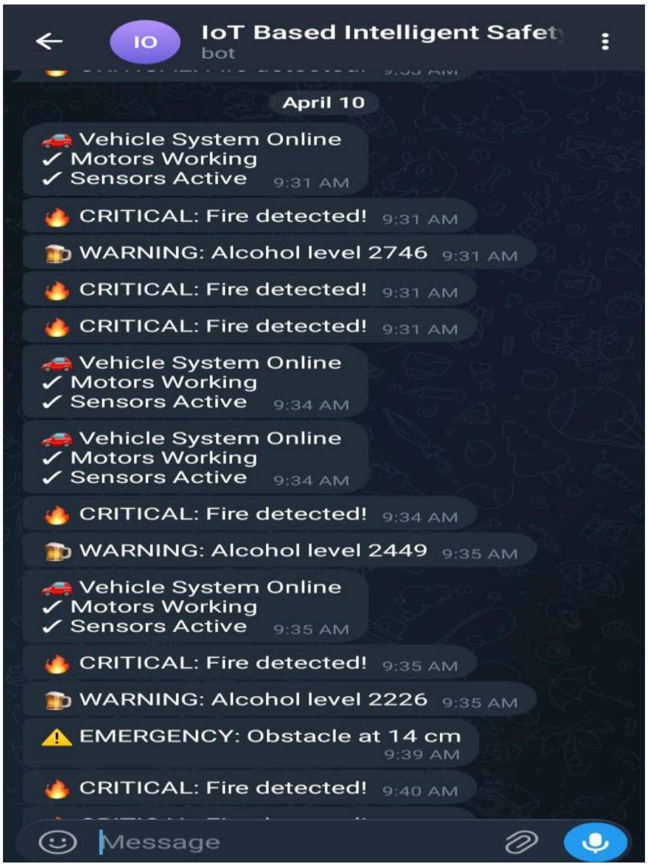

Fig-7: Telegram alert for vehicle safety system

The implementation stage of the project involves the successful development and integration of the IoT-based vehicle safety monitoring system, as shown in Fig 4. The system integrates the ESP32 microcontroller with multiple sensors and a real-time dashboard interface, enabling continuous monitoring of parameters such as temperature, humidity, alcohol level, and air quality, as displayed in Fig 5. In addition to environmental monitoring, the system incorporates Automatic Speed Control using Traffic Sign Recognition, where detected speed limits are set as thresholds, and the ESP32 continuously compares them with the vehicle's current speed; if the limit is exceeded, an instant warning is generated, as shown in Fig 6. Furthermore, the system enhances safety through Emergency Alerts and Prevention mechanisms by generating real-time warning messages such as "High Alcohol Level Detected," "CRITICAL: Fire-Detected," and "EMERGENCY: Obstacle 14 cm," as illustrated in Fig 7, thereby preventing unsafe vehicle operation and ensuring timely alerts to both the driver and remote users.

VI. CONCLUSION AND FUTURE WORK

Conclusion:

The proposed IoT-Based Vehicle Safety Monitoring System using ESP32 and multiple sensors effectively enhances vehicle safety by detecting hazards such as alcohol, fire, poor air quality, abnormal temperature, and obstacles in real time, providing timely alerts to the driver. The system demonstrates good accuracy, reliability, and cost-effectiveness, making it suitable for smart vehicle applications; however, its performance may be affected by challenges like sensor calibration issues, environmental noise, and scalability under extreme conditions. Despite these limitations, the system offers a strong and practical solution for improving driver awareness and reducing accident risks in modern transportation.

Future Work:

The proposed IoT-based vehicle safety and speed control system can be further improved to enhance its accuracy, functionality, and real-world applicability. One significant enhancement involves the adoption of advanced deep learning algorithms for traffic sign detection and recognition. These models can improve detection performance under challenging conditions such as low illumination, partial occlusion, and complex backgrounds. The system can also be expanded by integrating GPS-based location services to enable geo-fencing and location-aware speed control. This would allow automatic regulation of vehicle speed in designated zones such as school areas, hospitals, and accident-prone regions, thereby improving safety compliance. Additionally, the IoT framework can be strengthened through enhanced cloud integration, enabling large-scale data storage, real-time analytics, and remote monitoring. Such capabilities are particularly useful for fleet management systems, where centralized monitoring and control of multiple vehicles are required.

Future developments may also include the incorporation of advanced driver assistance features such as lane detection, driver drowsiness monitoring, and predictive collision avoidance systems. These additions would transform the system into a more comprehensive and intelligent driver support platform. Furthermore, optimization of both hardware and software components can be carried out to reduce system latency, improve processing efficiency, and ensure reliable real-time performance. However, these enhancements will improve the robustness, scalability, and effectiveness of the proposed system, making it more suitable for deployment in modern intelligent transportation and smart mobility applications.

VI. REFERENCES

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