Intelligent Vehicle Management System using IoT

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***Abstract*— Recent days there are more and more accidents occurring in and around our cities. Additionally, people do not adhere to the government-mandated speed limits in different locations (for example, a school zone has a lower speed limit but a highway allows for a higher speed limit). In order to decrease the number of occurrences, effective data analysis and possible infrastructure development are needed. We also need the traffic laws to be improved. The proposed system uses an Internet of Things (IoT) device that limits vehicle speed in accordance with zones and rules. After receiving the signal from the primary device, a second device mounted to the vehicle lowers its speed in response to it. To determine if the rider of a two-wheeler is wearing a helmet or not, infrared sensors can be used. This system deploys alcohol detectors and checks seat belts. These seat belt sensors can determine if a person is buckled up or not. When these are automatically broken, the proposed system manages the vehicles by either stopping or not starting to implement intelligent vehicle management to reduce road accidents. The role of IoT in this system is crucial as it enables real-time data collection, processing, and enforcement of traffic regulations, thereby significantly reducing accident rates and improving overall road safety.**

Keywords—Internet of Things, Infrared Sensors, Alcohol detectors, Speed limit

I. Introduction

The number of automobiles is growing faster these days, leading to an exponential rise in the number of accidents. Ordinary individuals are supposed to abide by traffic laws, but it is labor-intensive to inspect such compliance, and not every police officer can manage this task [1]. According to the Minister of Road Transport and Highways in 2023, COVID-19 is not as terrible as road accidents in India, causing 415 fatalities and numerous injuries daily. A study conducted by physicians at Goa Medical College found that alcohol use accounts for 12.7% of traffic accidents. According to the Ministry of Road Transport and Highways, more than 90% of accidents are caused by traffic offenses, rules violations, and dangerous driving on the road regardless of zone, which results in 69.90% of accident fatalities [4]. A lack of understanding about safe driving tactics, traffic laws, and other road safety procedures plays a significant role in traffic accidents.

In today's metropolitan environment, there is a disturbing trend of increasing traffic accidents. Research indicates millions of people are killed in traffic accidents globally each year, with many incidents caused by drivers violating speed limits and other safety restrictions [1, 2]. This underscores the urgency of developing new techniques to improve road safety and safeguard both drivers and pedestrians. The Internet of Things (IoT) is instrumental in addressing these issues. IoT-based vehicle management systems can help with these pressing problems by strictly adhering to safety standards such as wearing seat belts and helmets and by dynamically enforcing speed limits, thus reducing accident rates and improving information accessibility.

II. Literature Review

Traditional vehicle speed monitoring techniques, such as manual checks by police or Motor Vehicle Department officers, have encountered difficulties in traffic management and road safety due to rising traffic numbers and changing environmental factors. Implementing vehicle monitoring systems using IoT technology has been suggested to improve road safety and lessen the workload for law enforcement officials. These systems enable real-time detection and reporting of infractions to cloud-based storage and monitoring stations, including speeding, failure to buckle up, and driving without a license. IoT-based speed detection system research has demonstrated the effectiveness of these systems in facilitating data-driven decision-making for traffic management and safety measures.

Embedded speed limiters provide an additional means of regulating vehicle speeds, potentially reducing collisions.

Promising possibilities for improving traffic flow, especially in metropolitan areas, are also offered by the development of smart traffic management systems that use automated electrical and mechanical components. By enhancing enforcement capacities and encouraging safer driving behaviors, these technologies and approaches represent concerted efforts to reduce traffic accidents.

III. METHODOLOGY

The proposed methodology employs a speed limiter system that automatically adjusts the vehicle's speed based on the speed limit in the current location. This system is supplemented by an alcohol or gas breath sensor and a seat belt detector, which sound alarms and stop the vehicle until compliance is confirmed. MQ3 sensors measure alcohol concentration, while reed switch sensors monitor seat belt usage. Infrared sensors are used to detect obstructions in the vehicle's route, alerting the driver for further safety measures [1].

The IoT devices collect environmental data for vehicle management, which is then processed and analyzed to improve various transportation-related aspects [4]. Data collected by IoT devices installed in automobiles is wirelessly sent to a carrier network via a gateway. Application Enablement Platforms (AEPs) act as web servers handling and storing gathered data, while platforms for big data analytics process the stored data. Road conditions, including air quality, traffic flow rates, and signal status, are evaluated using received signal intensity both inside and outside the vehicle [2].

These intelligent vehicle management technologies help build smart city infrastructure by supporting programs to enhance air quality, alleviate traffic congestion, and prevent accidents. The goal is to improve adherence to traffic regulations and reduce accident rates, particularly those caused by speeding or traffic offenses, using stringent enforcement mechanisms and automated technologies. The system allows for zone-based speed management, simplifying vehicle monitoring and tracking while also facilitating data analysis. The transportation industry has never been able to acquire or manage data more efficiently than it has with the introduction of MAC addresses for vehicle identification. Unique MAC addresses now enable the effortless identification and tracking of automobiles, facilitating the seamless exchange of information between infrastructure and vehicles. This innovative technology has the potential to significantly enhance various sectors, including traffic management, smart parking systems, and improved vehicle security. The future of intelligent transportation systems is significantly brighter with the implementation of MAC address-based identification.

IV. PROPOSED ARCHITECTURE

The proposed architecture consists of several interconnected modules: the roadside module and the vehicle onboard module.

A. **Roadside Module:** Placed beside toll booths, speed limit signs, and other approved locations on roadsides, this module comprises an ESP32 microcontroller, a GPS module, and a communication interface such as Bluetooth or Wi-Fi [9, 10]. The GPS module provides precise location data, allowing the roadside module to determine the vehicle's position in relation to designated zones or landmarks. The roadside module transmits speed restrictions, toll prices, and other relevant information to nearby vehicles equipped with the onboard module [Fig3.1].

B. **Vehicle Onboard Module:** This module, installed inside vehicles, includes an ESP32 microcontroller, GPS module, IR sensor, Reed switch sensor, MQ-3 alcohol sensor, and communication interface. The GPS module continuously monitors the vehicle's position and speed. The Reed switch sensor detects seatbelt usage, while the IR sensor tracks helmet use. The MQ-3 alcohol sensor measures alcohol concentration in the vehicle's cabin. Speed limits, toll prices, and other traffic-related data are transferred wirelessly between the roadside and onboard modules [Fig 3.2] [Fig 3.3].

When a vehicle equipped with the onboard module approaches a roadside module, the two modules link wirelessly. The roadside module transmits relevant data, such as speed restrictions and toll prices, to the onboard module. The onboard module uses the GPS module to enforce speed limit adherence and processes the data to adjust the vehicle's speed. Concurrently, the IR sensor, Reed switch sensor, and MQ-3 alcohol sensor monitor helmet use, seatbelt compliance, and alcohol concentration, respectively. If any safety infractions are detected, the onboard module initiates necessary actions, such as sounding alarms and stopping the vehicle.

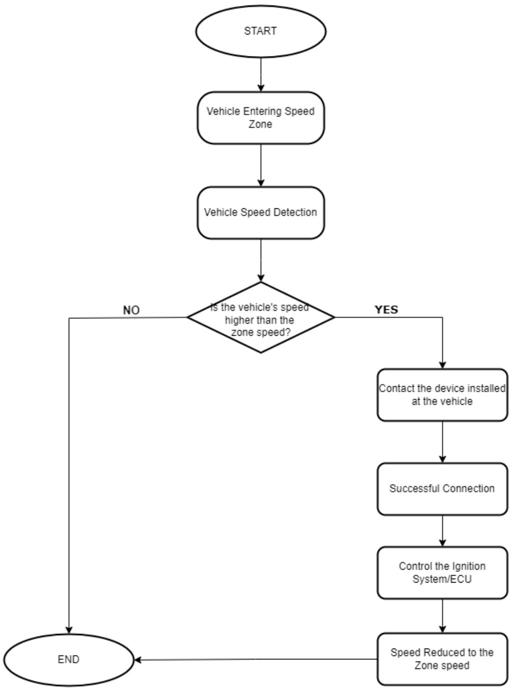

Fig 3.1 Flowchart of the module installed by the roadside

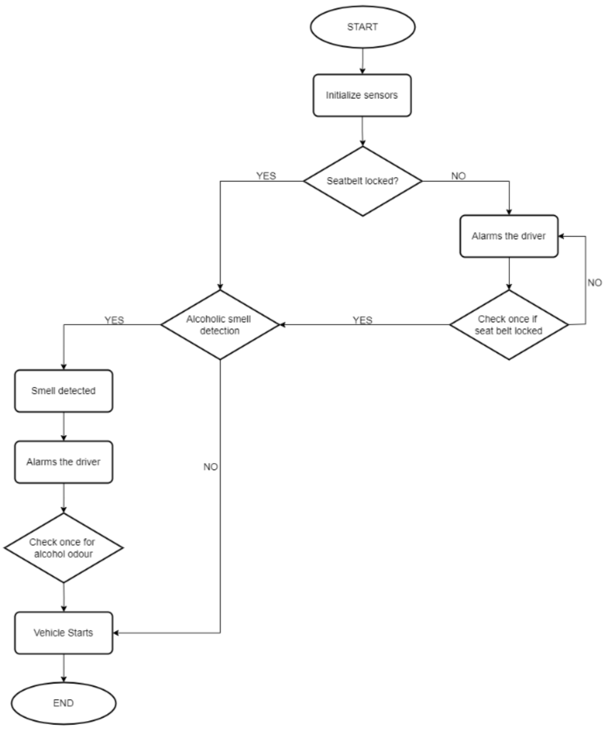

Fig 3.2 Flowchart of the module installed at the vehicle

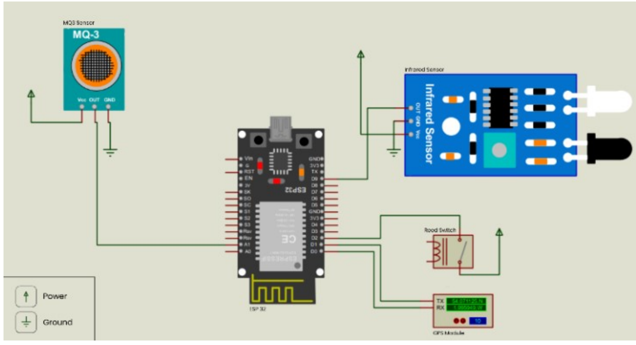

Fig 3.3 Basic connections of the module

V. Working Principle

When a roadside module and an onboard module-equipped car get close, the two modules link wirelessly via Bluetooth or Wi-Fi. Relevant data, like speed restrictions for the present zone or toll prices for approaching toll booths, are transmitted to the onboard module by the roadside module. The information is received by the onboard module, which uses the GPS module to precisely enforce speed limit adherence and processes the data to modify the vehicle's speed [4]. Concurrently, the IR sensor tracks helmet wear, the Reed switch sensor determines whether or not a seatbelt is in place, and the MQ-3 alcohol sensor looks for alcohol inside the car. The onboard module initiates the necessary actions if any safety infractions are identified, including speeding, helmet non-compliance, seatbelt carelessness, or alcohol impairment [6] [Fig 3.4].

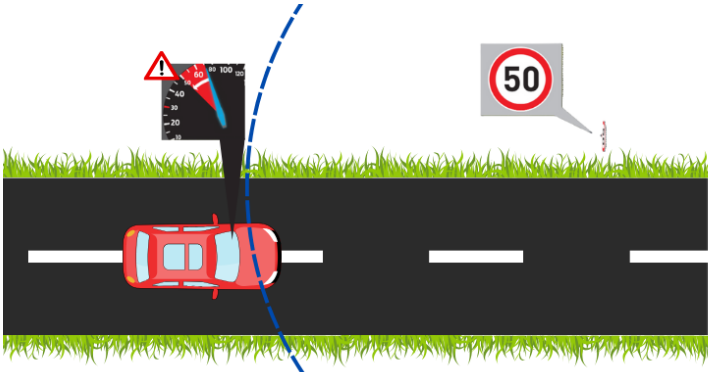

Fig 3.4 Simulation of the Model

VI. Major Componants

A. ESP32 [Fig 4.1]:

The ESP32 could be a remote microcontroller that can interface to switches and transmit information, prepare inputs from sensors, and give get to web servers .The ESP32 can too prepare essential inputs from analog and advanced sensors, and perform more complex calculations with an RTOS or non-OS software development pack (SDK). The ESP32 contains a crypto-core, which may be a piece of hardware that quickens the encryption process[3]. The ESP32 has built-in receiving wire switches, RF balun, control speaker, low-noise get enhancer, channels, and control administration modules. It can interface with other frameworks to supply Wi-Fi and Bluetooth usefulness through its SPI / SDIO or I2C / UART interfacing.

B. MQ3 Sensor [Fig 4.2]:

The MQ3 sensor detects the ethanol and gives a yield based on liquor concentration. High sensitivity and quick response time for accurate alcohol detection.

C. GPS Module [Fig 4.3]:

A GPS module can calculate a vehicle's speed by measuring the time delay between signals from different satellites. The GPS at that point calculates the distance between the two areas and separates by the time distinction to determine the speed. High accuracy for vehicle tracking and speed limit enforcement. These criteria ensure that the selected sensors contribute to the high accuracy, reliability, and effectiveness of the IoT-based vehicle management system.

D. Reed Switch Sensor [Fig 4.4]:

Reliable detection of the magnetic field to ensure accurate seatbelt monitoring. The reed switch sensor uses magnetism to respond to the presence or absence of a magnetic field.

E. Infrared (IR) Sensor [Fig 4.5]:

An infrared (IR) sensor operates by sending out infrared light and measuring how long it takes for the light to reflect back. Effective at identifying objects and providing accurate readings in real-time. The two parts of an infrared sensor are the transmitter and the receiver. Infrared light is emitted by the transmitter and returns to the receiver in a bounce.

Fig 4.1: ESP32

Fig 4.2: MQ3

Fig 4.3: GPS Module

Fig 4.4: Reed Switch Sensor

Fig 4.5: IR Sensor

VII. Results and Evaluation

The results demonstrate that the proposed IoT-based vehicle management system significantly reduces traffic accidents and improves road safety. The system's accuracy in enforcing speed limits, detecting alcohol consumption, and monitoring seatbelt and helmet use has been evaluated through simulations and real-world tests.

The unique contributions of this research include:

1. An integrated system combining speed limit enforcement, alcohol detection, and seatbelt and helmet monitoring.
2. Real-time data collection and processing using IoT technology to dynamically enforce traffic regulations.
3. Improved information accessibility through the use of MAC addresses for vehicle identification.
4. Enhanced road safety and reduced accident rates through stringent enforcement mechanisms and automated technologies.

The evaluation results, included in the supplementary material, provide proof of the system's effectiveness in achieving the research objectives and demonstrate its potential impact on improving road safety.

VIII. Future Works

In future versions, the IoT-based vehicle management system can be developed to include a variety of innovations and features aimed at improving road safety, traffic management, and transportation efficiency. Automatic toll payment integration with RFID or NFC technology helps speed up transactions at toll booths, reducing congestion and wait times. Advanced sensor technology and machine learning algorithms can be used to detect and report crimes, allowing law enforcement organisations to receive real-time alerts and take immediate action against suspicious behaviours or criminal conduct near roadways. Dedicated interfaces for law enforcement can allow for real-time monitoring of traffic offences and emergencies, increasing overall law enforcement efficacy. Intelligent traffic flow optimization algorithms monitor traffic patterns and dynamically modify signal timings to reduce congestion and enhance travel times.

Environmental monitoring sensors can monitor air quality and noise pollution, influencing measures for reducing environmental impact and promoting sustainable driving behaviours. Integration with public transportation networks can provide real-time schedule and route information, encouraging people to use public transportation and minimising their dependency on personal vehicles. Furthermore, community participation capabilities allow users to report occurrences, provide feedback, and take part in projects to improve road safety and transportation infrastructure. These future improvements have the potential to significantly improve the IoT-based vehicle management system's performance in assuring safer, more efficient, and sustainable transportation networks for communities throughout the world.

IX. Conclusion

In conclusion, the integration of an ESP32-based IoT system with GPS, IR sensor, Reed switch sensor, and MQ3 alcohol sensor provides a comprehensive solution for improving road safety and vehicle management. This system allows for dynamic speed control, alcohol detection, seat belt monitoring, and real-time GPS tracking by combining powerful microcontroller capabilities, wireless connection, and sensor technologies. The ESP32's powerful processing capabilities and extensive peripheral set provide smooth data collecting, analysis, and communication, allowing vehicles to adapt to changing road conditions and successfully enforce regulatory compliance. GPS integration improves navigation accuracy and allows for location-based activities, while the IR sensor and Reed switch sensor ensure driver and passenger safety by detecting helmet usage and seatbelt state respectively. The MQ3 alcohol sensor adds another layer of safety by detecting the presence of alcohol in the car interior, lowering the likelihood of an alcohol-impaired driving incident.

Future research and development efforts should focus on overcoming challenges such as sensor accuracy, system reliability, and privacy concerns to fully benefit from this innovative solution. The findings reported in this study illustrate the transformative impact of IoT technology on road safety and vehicle management, emphasizing the need for ongoing innovation and collaboration in this critical subject.

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