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Autonomous Vehicle Health Monitoring and Driver Safety System

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Abstract: This project is to modernize vehicle maintenance processes and enhance driver safety through the integration of advanced autonomous and Internet of Things (IoT) technologies. Current vehicle service methods are impeded by manual inefficiencies, delayed maintenance, insufficient transparency, and the potential misuse of vehicles during servicing. These deficiencies not only jeopardize vehicle health but also pose significant risks to driver safety. To address these challenges, this initiative develops an advanced system that incorporates real-time monitoring, predictive analytics, and automated safety measures. The system employs embedded sensors to continuously assess critical vehicle parameters, including oil levels, engine conditions, and accident notifications. The utilization of the ESP32 enables connectivity with a mobile IoT application, and an auditory alert system, represented by a buzzer, serves to indicate faults and issues.The vehicle is equipped with a temperature sensor, vibration sensor, and fuel leakage sensor. In the event that any of these sensors are activated, the vehicle will automatically enter an off state. Subsequently, we will implement RFID technology for scanning and detection, which will facilitate the reactivation of the vehicle..
Keywords: ESP32 microcontroller, temperature sensor, vibration sensor, fuel leakage sensor, RFID module, buzzer, and a mobile IoT interface

I. INTRODUCTION

The proposed project seeks to transform conventional vehicle maintenance and safety protocols through the integration of advanced autonomous systems, Internet of Things (IoT) connectivity, and sensor-based monitoring. Traditional vehicle servicing often encounters inefficiencies, including manual diagnostics, insufficient real-time updates, delayed responses to maintenance needs, and the potential for vehicle misuse during service periods. These shortcomings not only compromise the health and performance of vehicles but also endanger driver safety. In order to overcome these challenges, this project introduces a sophisticated and proactive system that leverages ESP32-based IoT connectivity, real-time sensor feedback—including monitoring of temperature, vibration, and fuel leakage—and biometric assessments. Central to this system are embedded sensors and an RFID-based safety mechanism, which collaboratively monitor essential vehicle parameters, such as engine temperature, fuel system integrity, and abnormal vibrations, to identify faults or potential hazards. Upon the detection of any critical issues, the system autonomously disables the vehicle and activates a buzzer alarm, necessitating RFID verification to resume operations.

This feature ensures that vehicle reactivation is restricted to authorized personnel, thereby enhancing security measures. Furthermore, the incorporation of biometric sensors for fatigue and distraction detection, alongside behavioral monitoring, significantly enhances driver safety. The complete system is interconnected with a mobile IoT application utilizing ESP32 technology, facilitating real-time notifications, fault logging, and remote monitoring capabilities. This innovative approach not only ensures heightened transparency and safety but also lays the foundation for a more reliable, data-driven, and autonomous vehicle ecosystem.

II. PROBLEM STATEMENT

Traditional maintenance and safety inspections of vehicles are predominantly reliant on visual assessments and reactive servicing. This methodology often results in delays in fault detection, heightened operational risks, and the potential for misuse during servicing. Conventional approaches are not equipped with capabilities for real-time monitoring, transparency, or predictive maintenance, which contributes to increased maintenance costs and diminished driver safety. Moreover, immediate mechanical issues, such as engine overheating, fuel leaks, or loose components, can be difficult to detect until they develop into significant problems.

Consequently, there exists a pressing need for an advanced sensor-based system that can automatically identify faults, provide real-time notifications to users, and mitigate unsafe driving conditions.

This system should also support remote monitoring through Internet of Things (IoT) integration and facilitate secure reactivation of the vehicle only after proper authorization, thereby ensuring safety and reliability in contemporary vehicle operations.

III. SYSTEM IMPLEMENTATION

This proposal outlines a system that employs sensor technology to monitor critical vehicle parameters in real time, thereby enhancing safety and reliability during operations. Traditional vehicle inspections are often performed manually, rendering them inadequate for continuous monitoring. To mitigate this issue, the proposed system integrates various sensors into the Engine Control Unit (ECU) to identify anomalies such as engine overheating, fuel depletion, insufficient braking force, and mechanical loosening. The system comprises a thermometer to monitor engine temperature, a fuel gauge to assess fuel levels, a brake pad sensor to evaluate braking pressure, and a vibration sensor to ascertain the integrity of mechanical fasteners, including screws and nuts. Upon detecting any irregularities, the system autonomously activates a buzzer alarm to notify the driver or designated personnel. In addition, all sensor data is transmitted to an Internet of Things (IoT) platform, facilitating remote monitoring and enabling timely interventions. This advanced configuration offers a proactive maintenance solution that significantly enhances vehicle safety and operational efficiency.

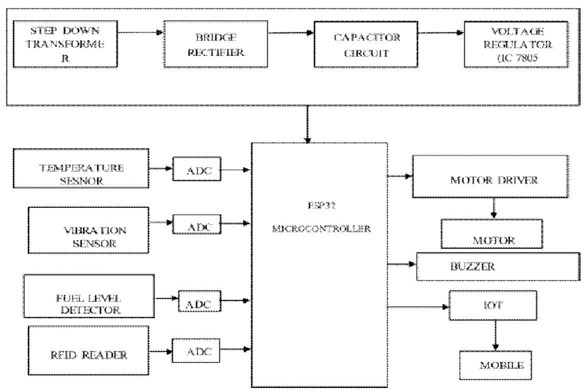

Fig.1. PROPOSED BLOCK DIAGRAM

IV. HARDWARE DESCRIPTION

1) ESP-32 WROOM

Built around the dual-core Xtensa® 32-bit LX6 processor, Espressif Systems created the ESP32-WROOM, a flexible and potent Wi-Fi and Bluetooth module. It is perfect for Internet of Things applications because it supports Bluetooth (classic and BLE) and Wi-Fi (802.11 b/g/n). It makes it simple to integrate with a variety of sensors and peripherals thanks to its numerous interfaces, which include UART, SPI, I2C, and up to 34 GPIOs. The module is well-known for its low power consumption, integrated security features, and compatibility with development platforms such as ESP-IDF and Arduino IDE. Wearable technology, embedded systems, smart home appliances, and industrial automation all frequently use it.

Fig. 2.ESP-32 WROOM

2) TEMPERATURE SENSOR*:*

The ADIY NTC Thermistor Temperature Sensor Module is a small and simple-to-use module that is intended for temperature sensing purposes. It has an NTC (Negative Temperature Coefficient) thermistor, which reduces its resistance as temperature rises, allowing precise thermal monitoring.

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The module offers analog (AO) and digital (DO) outputs for versatile interfacing with microcontrollers. The analog output provides a variable voltage proportional to the temperature, and the digital output is asserted when the temperature passes a threshold set by the onboard potentiometer. The module also has power and digital output indicator LEDs for immediate status feedback.

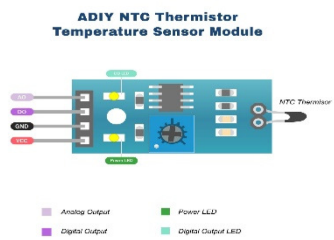

Fig. 3. TEMPERATURE SENSOR LM35

3) VIBRATION SENSOR

SW-420 Vibration Sensor Module is made to sense vibration or abrupt movement around it. The center of this module is the cylindrical black device (SW-420 vibration sensor) that has a spring mechanism within that is sensitive to mechanical interference. As the vibrations are sensed, the internal circuit causes a change in signal that can be digital-read. The module also has an LM393 voltage comparator and sensitivity adjustment potentiometer for precise vibration threshold adjustment. The module consists of three pins: VCC (power), GND, and DO (digital output). The power and signal state are shown through LEDs on the board. This sensor finds application in alarm systems, anti-theft, and project environments demanding motion or vibration

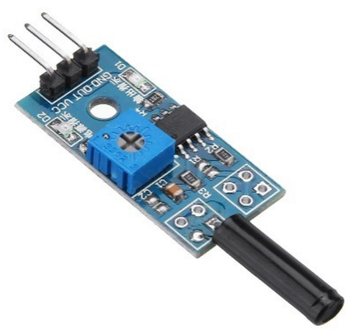

Fig.4..SW-420 VIBRATION SENSOR

4) FUEL LEAKAGE SENSOR

The sensor module depicted in the photo is a Rain Detection Sensor Module, which is frequently applied in weather monitoring and automation systems. It consists of two primary parts: a sensor board with uncovered parallel conductive tracks for sensing raindrops, and a control board that deals with the signal. When water connects the conductive tracks, the sensor sends a signal suggesting the occurrence of rain. The control board contains an LM393 comparator, a sensitivity trim potentiometer, and LEDs to indicate power (PWR LED) and digital output status (D0 LED). It has both analog output (A0) for proportional measurements and digital output (D0) for threshold detection. The module contains VCC, GND, DO, and AO connections and is thus suitable for use with microcontrollers such as Arduino. It's also commonly used in smart irrigation, weather stations, and automatic window-closing systems.

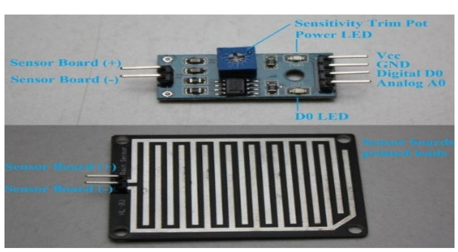

Fig. 5. FUEL LEAKAGE SENSOR

5) RFID READER AND TAG

The RFID-RC522 Module is a widely recognized and economical RFID reader/writer based on the MFRC522 integrated circuit. Operating at a frequency of 13.56 MHz, this module facilitates contactless data exchange with RFID tags and cards, such as the provided key fob and white card. It interfaces with microcontrollers through the SPI protocol, rendering it well-suited for applications involving Arduino, Raspberry Pi, and other development platforms. This module is frequently employed in areas such as access control, security solutions, attendance management, and inventory tracking. The RFID-RC522 is capable of reading and writing data to RFID tags within a typical range of 2 to 5 centimeters and is compatible with ISO/IEC 14443 Type A cards, which are commonly utilized invarious identification and NFCapplications.

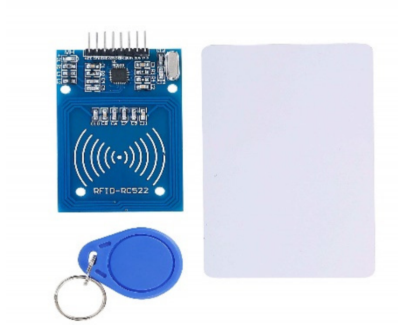

Fig.6. RFID READER AND TAG

V. METHODOLOGY

The system employs sensors to monitor critical vehicle parameters, thereby enabling the identification of hazardous fault conditions, such as excessive engine temperature, abnormal vibrations, and fuel leakage. Sensor data is analyzed by an ESP32 microcontroller, which compares the information against predefined thresholds to detect potentially dangerous situations. When any sensor is triggered, an audible buzzer alerts the operator, the vehicle's ignition is disengaged, and a restart is permitted only after an authorized RFID scan is conducted. Concurrently, real-time data is transmitted over Wi-Fi to a remote Internet of Things (IoT) mobile platform for effective monitoring and control. The primary fault response actions are delineated as follows:

- Audible Alerts: Activation of a buzzer to signify the detection of a fault.
- Vehicle Ignition Cut-off: Disabling of the vehicle's ignition upon exceeding established thresholds for temperature, vibration, or fuel leakage.
- Secure Restart: Authorization for vehicle restart is contingent upon the scanning of an approved RFID card by the driver or operator.
- Live Data Synchronization:Continuous data synchronization with a mobile application via Wi-Fi, facilitated by the ESP32 microcontroller.

System Execution

1) Data Acquisition

The system functions continuously to acquire real-time data through the utilization of a temperature sensor, a vibration sensor (SW-420), and a fuel leakage sensor. These sensors interface with the ESP32 microcontroller, which is responsible for reading and processing the data outputs. Furthermore, an RFID module is incorporated to identify authorized users, facilitating controlled vehicle operation.

2) Fault Detection and Processing

Each sensor is programmed with predefined safety thresholds. Upon the detection of abnormal values—such as an excessive engine temperature, unusual vibrations, or fuel leakage—the ESP32 activates an alarm buzzer and automatically deactivates the vehicle's ignition system. This prompt response is crucial for mitigating potential hazards and preventing additional damage or accidents.

3) Secure Restart Utilizing RFID

Once the vehicle has been disabled due to a fault, it remains inoperable until an authorized RFID tag is scanned. This protocol ensures that only designated personnel can restart the vehicle following the resolution of the fault. The system further verifies that the fault condition has returned to normal before permitting the restart.

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4) IoT Integration and Monitoring

By leveraging the onboard Wi-Fi capabilities of the ESP32, sensor readings and fault notifications are transmitted in real-time to a mobile application or cloud platform (such as Blynk or Firebase). This functionality allows users to monitor vehicle health, receive alerts regarding faults, access historical logs, and oversee vehicle activity remotely, thereby enhancing both safety and maintenance efficiency

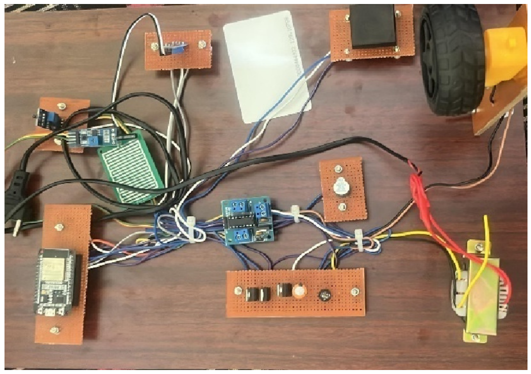

Fig.7. Autonomous vehicle health monitoring and driver safety system

VI. RESULT

The integration of temperature, vibration, and fuel leakage sensors facilitated real-time detection of critical vehicle issues. Upon the detection of any abnormal conditions—such as overheating, excessive vibrations, or fuel leakage—the system promptly activated an alarm to alert the user and automatically deactivated the vehicle's ignition system. This response mechanism proved essential in preventing potential accidents and damage, thus ensuring the safety of both the vehicle and its occupants. The utilization of the ESP32 microcontroller enabled seamless connectivity between the vehicle system and a mobile Internet of Things (IoT) application. This interface allowed users to receive immediate notifications regarding the vehicle's health status and sensor alerts. Additionally, real-time data logging and monitoring were accomplished, enhancing the capabilities for predictive maintenance. Users were able to access historical sensor data, thereby improving operational transparency and facilitating the early diagnosis of recurring faults.

This contributed significantly to reducing long-term maintenance costs and preventing unexpected breakdowns. Another significant achievement of the project was the enhancement of vehicle security and driver safety. The implementation of RFID-based access control ensured that the vehicle could only be restarted by an authorized individual following a fault-triggered shutdown. This measure prevented unauthorized usage and added a critical layer of operational control. Furthermore, biometric sensors monitored driver fatigue and distractions, issuing alerts and emergency notifications when abnormal behavior was detected

. This functionality promoted responsible driving habits and enhanced overall safety. In summary, the system demonstrated high reliability, rapid fault detection, and efficient communication between hardware and mobile platforms. The integration of IoT technology, sensor-based automation, and RFID authorization created a comprehensive solution for vehicle safety and maintenance. This project not only met its objectives of modernizing vehicle servicing but also established a benchmark for the incorporation of autonomous safety features in future smart vehicle systems.

VII. CONCLUSION

This paper effectively illustrates an innovative and sophisticated approach to vehicle maintenance and driver safety, utilizing the capabilities of Internet of Things (IoT) technology, sensor applications, and autonomous control systems. By integrating embedded sensors—including those for temperature, vibration, and fuel leakage—with RFID authentication and ESP32-based mobile connectivity, the system enables real-time fault detection, secure vehicle operation, and proactive maintenance notifications. The vehicle shutdown feature, when paired with RFID-based restart functionality, introduces a vital layer of safety and prevention against misuse, particularly in cases of significant faults. Furthermore, the incorporation of biometric monitoring to detect driver fatigue and distraction enhances overall safety by encouraging vigilant driving practices and mitigating accident risks.

The mobile IoT application functions as a centralized platform for real-time updates, fault logs, and historical data analysis, thereby improving the transparency and efficiency of vehicle diagnostics. In summary, this system successfully bridges the divide between conventional vehicle maintenance methodologies and the advancing technological landscape of autonomous vehicles.

It not only enhances operational performance and reduces operational costs but also instills confidence in the reliability and safety of smart transportation systems. This project establishes a robust foundation for the development of intelligent mobility and automobile health management solutions in the future..

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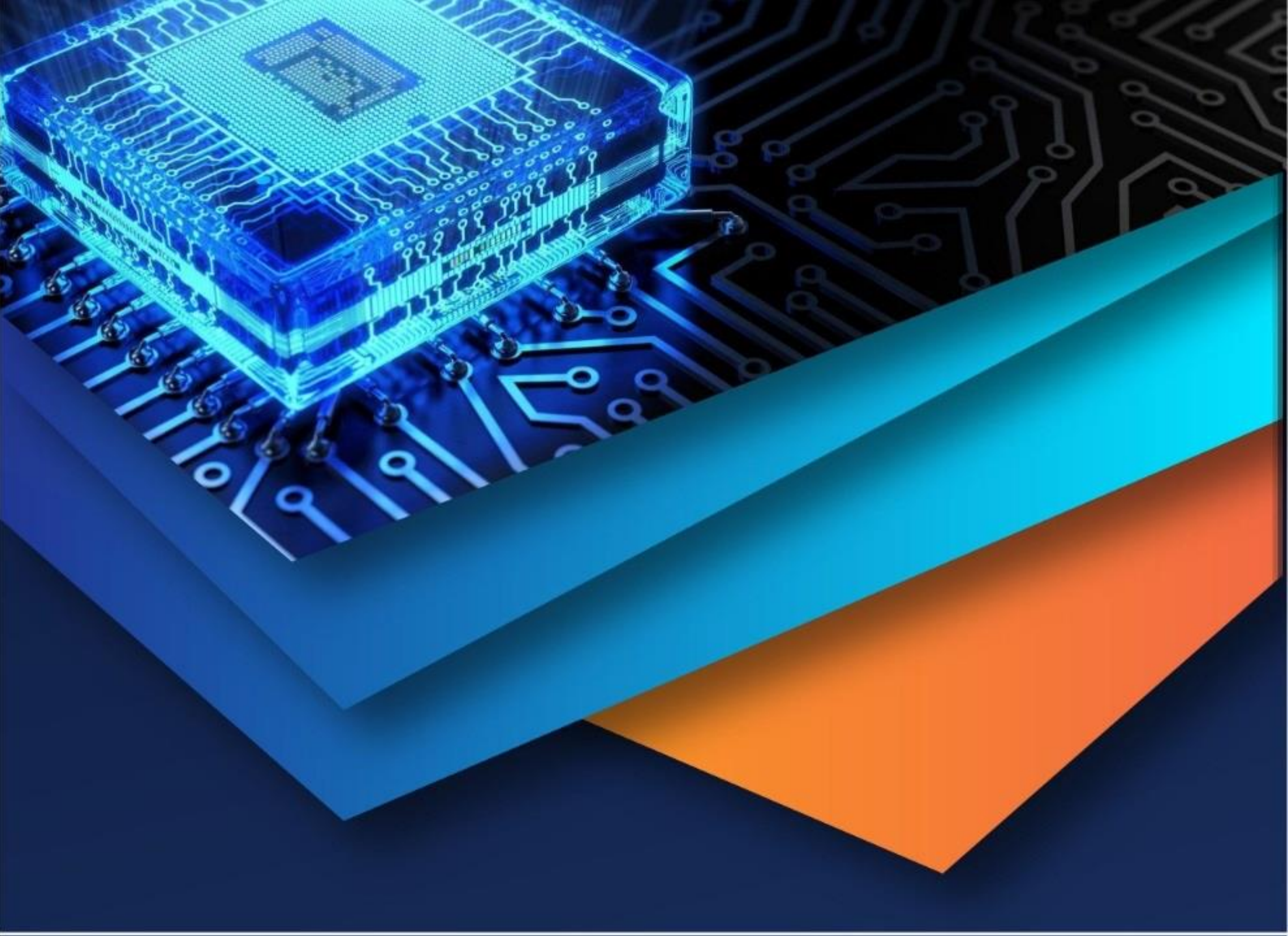

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