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Vehicle Accident Detection and Advancement System

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Abstract: Vehicles play a crucial role in modern life, offering unparalleled convenience and mobility. However, along with their myriad benefits, they also have various inherent risks,main reason among them being the occurrence of accidents. One pressing issue pertains to be the absence of a comprehensive tracking system, particularly in older vehicle models, to effectively monitor and respond to accidents. The primary objective of this work is to develop a robust accident detection system and implement advanced functionalities within vehicles, thereby enabling diverse applications. The devised system entails the transmission of accident data to a dedicated mobile application, facilitating real-time alerts to designated contacts. Additionally, the application furnishes essential vehicle metrics such as speed, RPM, and location, empowering users with comprehensive vehicle status insights.

Keywords: Accident alert system, Arduino, GSM, GPS.

I. INTRODUCTION

In contemporary times, the escalation in population numbers correlates with a proportional increase in vehicular density, consequently amplifying the incidence of accidents. Due to technological advancement, increase of vehicle usage, the frequency of accidents is increasing day by day while, accidents rank among the foremost causes of mortality worldwide [6] [4]. In recognition of this grave concern, it becomes imperative to devise a targeted solution for the timely detection of accidents [4]. Nowadays many vehicles are introduced with many smart response systems which can connect with a user mobile phone [8]. This paper not only offers a resolution for accident detection but also to imbue vehicles with intelligent functionalities such as exact location and less delay in messaging.

The Vehicle Accident Detection and Advancement System (VADAS) epitomizes a technological innovation poised to tackle the exigencies associated with accident detection. By harnessing advanced sensors and sophisticated data processing algorithms, VADAS facilitates expeditious detection of vehicular accidents, alongside facilitating the incorporation of multifaceted advancements in vehicles.

The primary aim is to identify vehicular accidents promptly and relay pertinent alerts, complete with location details, to designated contacts. Furthermore, the project entails the acquisition of vehicle data encompassing metrics such as speed, RPM, temperature, and engine diagnostics, which is subsequently transmitted to the user's mobile device.

This paper, ascertain the most effective algorithms for accurately and reliably detecting vehicle accidents. An endeavor to discern the nuances that distinguish normal driving conditions from accident scenarios. Additionally, the paper explores the optimal communication protocols and interfaces for transmitting accident alerts seamlessly. The integration of VADAS into existing vehicle systems poses challenges that warrant investigation, alongside an exploration of the potential limitations.

Furthermore, an effort to explore the feasibility of integrating diverse sensors and effecting modifications as per specific requirements is presented.

A. Existing Models

Several literatures and models have been developed which delve into diverse facets of the Vehicle Accident Detection and Advancement System (VADAS) in the view to enhance safety, faster messaging to emergency contact and incorporating advanced technologies etc. [3], [5]. Scholarly inquiry has traversed myriad sensor-based methodologies aimed at accident detection and vehicular monitoring, encompassing camera-based systems, GPS-GSM systems, OBD2 systems, and IR-based systems.

Furthermore, this section expounds upon the intrinsic significance of various existing systems in augmenting road safety standards.The system developed by [6] alerts nearest hospitals about upcoming medical aid. Also [6] can sense the tilt in the vehicle and heartbeat of the user to identify an accident. This system uses GSM and GPS modules to send messages to user mobile phones.

While, [1], designed a real-time tracking position of a vehicle especially in the case of food related business, also an event of theft using Arduino Uno, GPS, GSM modules. This system collects the latitude and longitude information value of the desired vehicle and conveys it to the emergency contacts.
[2], developed a system which recognizes fire accidents and notify nearest fire station using the GSM module. A similar accident detection system developed by [10], [13] uses various components such as latitude, longitude information and alert nearest emergency service or contacts.
Evidentiary discourse posits that the integration of machine learning algorithms and artificial intelligence methodologies augments the efficacy of accident detection systems. The capacity to scrutinize real-time data facilitates a clear delineation between customary driving comportment and potential accident scenarios.

II. COMPARATIVE ANALYSIS

A. GPS-GSM Based System

The GPS-GSM based systems [13], [6], [4] leverage global positioning technology to precisely track the geographical coordinates of vehicles, along with monitoring their speed and regular routes. While acknowledged for its cost-effectiveness, this system is marred by several limitations. Specifically, its predictive capabilities are often compromised, and it encounters significant challenges when deployed in urban environments.

B. Camera Based System

Camera-based systems [4] leverage computer vision technology to discern abrupt alterations in road conditions and driver behavior [14]. By scrutinizing camera footage, these systems can identify accident scenarios and monitor vehicular activity. However, it is pertinent to note that this system entails significant costs, necessitating optimal hardware specifications and high-resolution cameras for effective operation.

C. On-Board Diagnostics II (OBDII) Based System:

The OBDII based systems [5], [11], [12], [15] operate by retrieving data from the vehicle's Electronic Control Unit (ECU) utilizing Controller Area Network (CAN) communication protocol. By establishing direct communication with the vehicle's ECU, these systems facilitate the seamless monitoring of vehicle data and the timely detection of accidents. Furthermore, it afford access to information from all pre-installed sensors within the vehicles. Notably, the implementation of such a system necessitates a profound understanding of vehicle ECUs, CAN communication protocols, and the intricacies of reverse engineering.
Altogether, each system exhibits its distinct set of advantages and limitations. A comprehensive system may incorporate multiple sensors and leverage machine learning algorithms to optimize performance across diverse environmental conditions.

III. METHODOLOGY

The VDAS entails a comprehensive amalgamation of hardware and software components designed to ensure accuracy in accident detection and facilitate the dissemination of alert messages. The operational framework of this system necessitates the utilization of hardware components to establish communication with vehicles, complemented by software functionalities responsible for processing the data acquired from sensors and the Electronic Control Unit (ECU).

A. System Architecture

The primary objective of this system is to monitor vehicles traversing roadways, consistently gathering pertinent data including location, speed, and accelerometer readings, and subsequently transmitting this information to the designated receiver. A schematic representation of the hardware process is elucidated in Figure 1 below.
The particular design is purposed to facilitate the transmission of vehicle location and pertinent data to the recipient's end. A critical component of this endeavor lies in the transmission of data from the receiver's side, necessitated by the utilization of the Wi-Fi communication protocol. To manage and procure data from various sensors, this system employs the Arduino UNO microcontroller. The acquisition of system location is facilitated by a GPS module interfaced with the Arduino, while communication with the vehicle's Electronic Control Unit (ECU) is achieved through a CAN communication module. Subsequently, all acquired data is relayed to the user's mobile application, where it is presented and connected in real-time.

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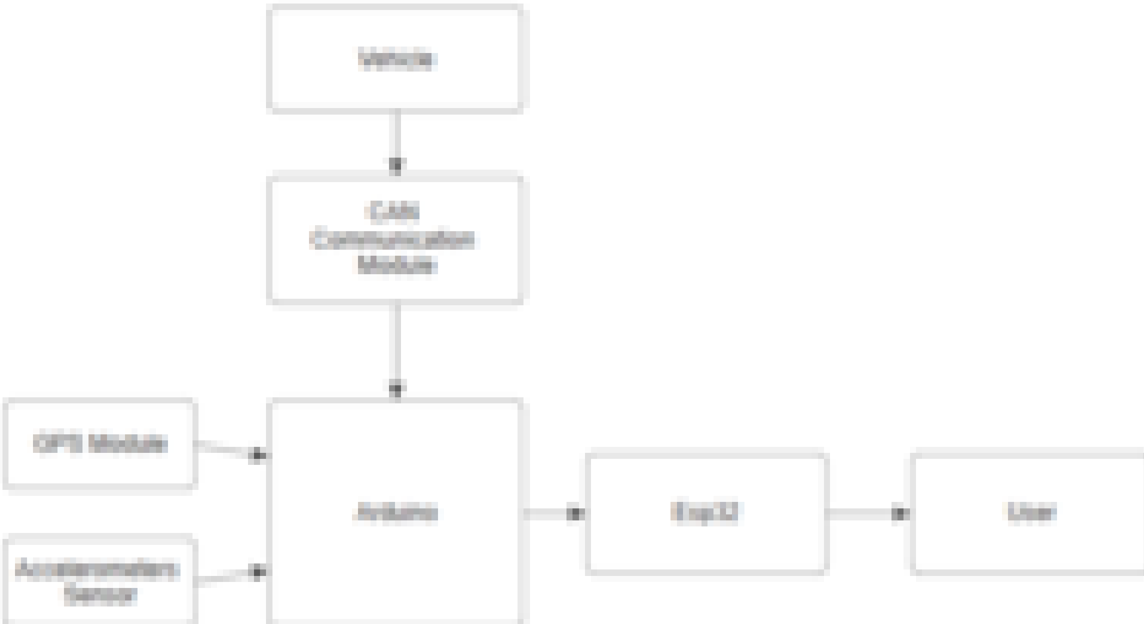

Figure 1: Block Diagram of Vehicle Accident Detection and Advancement System

B. Hardware Components:

1) Arduino UNO: The Arduino UNO (See Fig 2) serves as the central component of the project, functioning as a microcontroller board responsible for orchestrating the operation of all sensors and retrieving data from the Electronic Control Unit (ECU). Each sensor within the system transmits its data to the Arduino UNO, which subsequently processes these signals, converting them into a readable format before displaying the information on the screen.

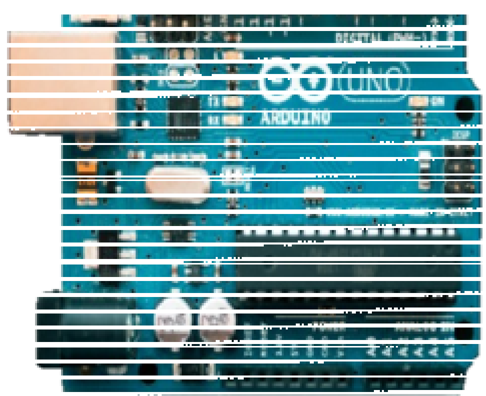

Figure 2: Arduino UNO

2) GPS module: The GPS module, namely the NEO6m GPS (See Fig 3), serves the purpose of geolocation of vehicles on the Earth's surface by capturing the x and y coordinates of positions. Following the acquisition of location data, this module transmits the information to the Arduino, which, in turn, utilizes the ESP32 microcontroller to display the vehicle's location on the user's device. Operating at a frequency of 1 Hz, the NEO6m module ensures consistent and precise location tracking.

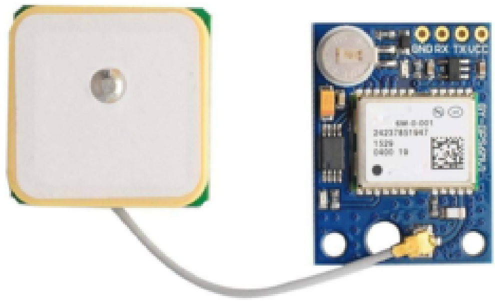

Figure 3: NEO6m GPS module

3) ESP-32: The ESP32 (Fig 4) microcontroller board is equipped with Wi-Fi and Bluetooth functionalities, rendering it instrumental in transmitting sensor data to the user's device in this project. Moreover, the ESP32 facilitates the integration of additional sensors, thereby enhancing the system's capabilities.

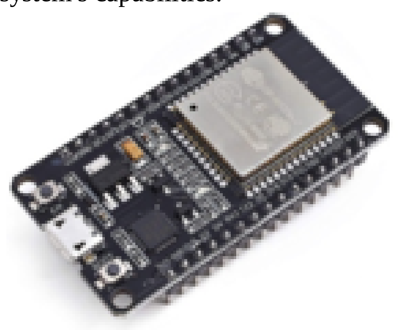

Figure 4: ESP32

4) Accelerometer sensor: The accelerometer sensor, is an integral part for accident detection, captures data pertaining to the X, Y, and Z axes. Through the analysis of these axis values and the application of specialized algorithms, the occurrence of an accident can be discerned. The MPU6050 module (See Fig 5) serves as the accelerometer sensor in this context, detecting changes in axis values and relaying them to the Arduino. Subsequently, the Arduino employs an algorithm to identify accident scenarios and promptly alert the user.

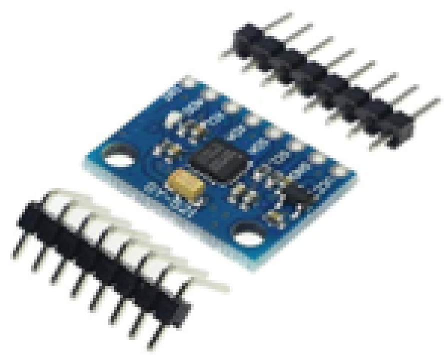

Figure 5: MPU6050 module

5) CAN Communication Module: The CAN Communication Module, exemplified by the MCP2515 (See Fig 6), is employed to extract vehicle data from the OBD port. This module serves as an intermediary between the vehicle's onboard systems and the Arduino, facilitating the transmission of vehicle status information to the user's device. Facilitating bidirectional communication via CAN high and CAN low channels, the MCP2515 module contributes to comprehensive vehicle monitoring and reporting.

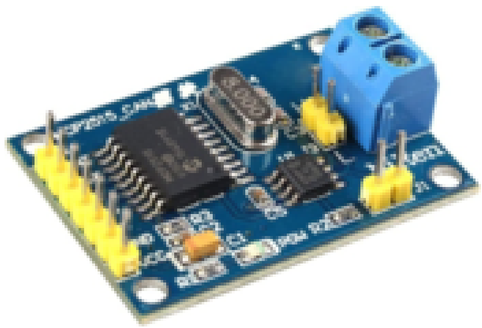

Figure 6: MCP2515 CAN Communication Module

6) OBDII female port: The OBDII female port (See Fig 7) serves as a conduit for connecting the CAN module to the vehicle's OBD port. It facilitates the direct integration of wires onto the CAN high and CAN low pins within the OBD port, thereby enabling seamless communication between the CAN module and the vehicle's on board diagnostics system.

Figure 7: OBDII female port

7) Toggle Switch: The toggle switch serves as a mechanism for interrupting the power connection between the Arduino and other sensors, thereby facilitating power conservation.
8) Power Connector: The power connector functions as the means to supply power to all sensors and the Arduino board via external batteries. It operates on a power supply ranging between 5 to 7 volts.

C. Software Components:

1) Arduino IDE: The Arduino Integrated Development Environment (IDE) represents an embedded software platform utilized for programming microcontrollers. It serves as a versatile tool enabling diverse functionalities, encompassing data acquisition from sensors, implementation of accident detection algorithms, and visualization of outputs via the serial monitor.
2) Mobile Application: To facilitate the collection of vehicle data from the user's perspective, a mobile application has been developed using the Flutter framework. This application serves as an intuitive interface for presenting data in a structured manner. Endowed with customization capabilities, our proprietary mobile application empowers users to tailor data presentation to their preferences. Furthermore, it facilitates the addition of emergency contacts for the dispatch of alert messages, as well as provides real-time insights into critical vehicle metrics such as engine status, speed, and more.

D. Hardware Configuration:

The hardware configuration of the VADAS system is shown in Figure 8.

1) The accelerometer sensor has been meticulously integrated into the PCB board to precisely gauge acceleration along the X, Y, and Z axes.
2) The system incorporates GPS modules seamlessly integrated within the board, facilitating the transmission of precise location data to the Arduino microcontroller unit.
3) A microcontroller equipped with an appropriate power supply unit.

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4) A communication module has been integrated with the Arduino platform to facilitate communication with mobile devices, enabling the transmission of data via a Wi-Fi network.
5) The CAN high and CAN low pins are interlinked with the OBDII port to establish communication with the vehicle (See Fig 9).

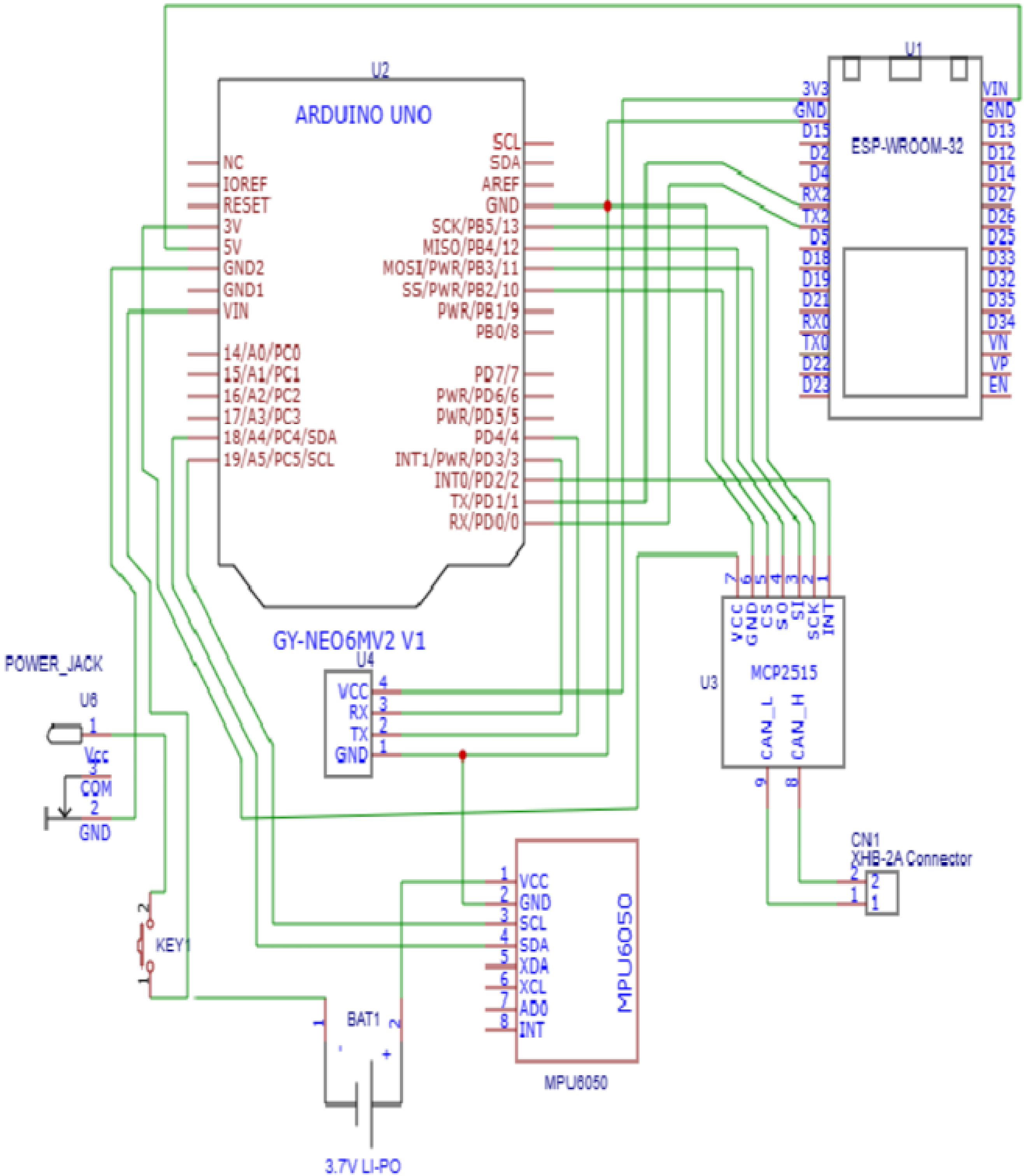

Figure 8: Circuit Diagram of Hardware configuration.

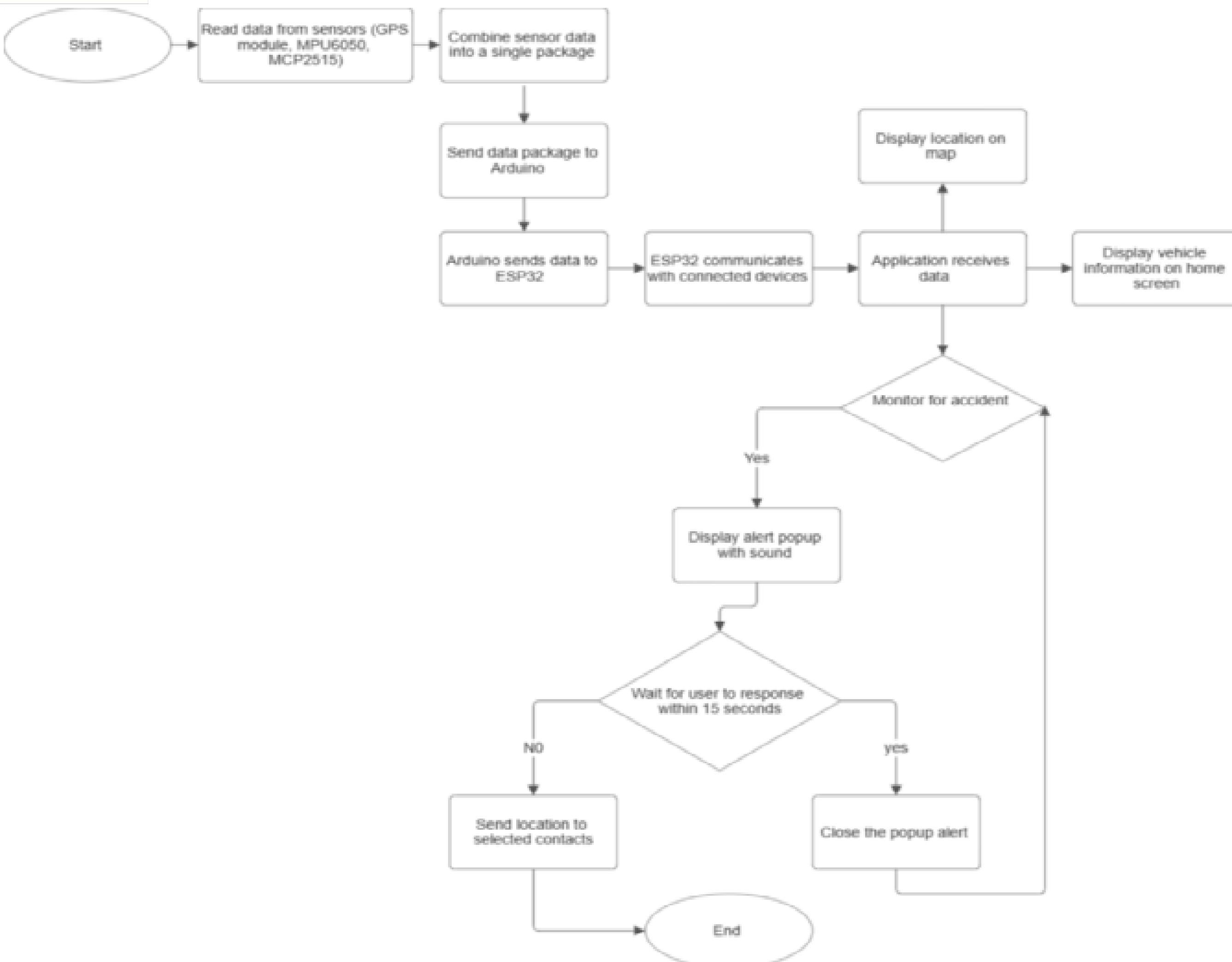

Figure 9: Flowchart of Vehicle Accident Detection and Advancement System

To check the accident condition VADAS is using MPU6050, which collects the values of three axes (x, y, z) and sends these values to the Arduino. After that, the Arduino uses the below method for detecting the accident.
For each time step‘t’, the accelerometer measures the acceleration along three axes:$a_x(t)$, $a_y(t)$, $a_z(t)$.
For each axis *i*(where *i* can be *x*, *y*, *z*) the changes in acceleration $\Delta a_i(t)$ is calculated as:

$$\Delta a_i(t) = |\Delta a_i(t) - \Delta a_i(t-1)|$$

Here, $a_i(t)$ represents the current acceleration along axis *i*, and $a_i(t-1)$ represents the previous acceleration along the same axis.
The total change in acceleration at time t is $\Delta a_{total}(t)$ computed by summing the absolute changes for all axes:

$$\Delta a_{total}(t) = \sum_{i=x,y,z} \Delta a_i(t)$$

An accident is detected when the total change in acceleration exceeds a predefined threshold.

$$\text{Threshold} = 180.0$$

$$\Delta a_{total}(t) > \text{Threshold} \; . \; . \; . \; . \; . \quad (1)$$

If the condition (1) is true then it indicates a significant deviation from the normal motion of the vehicle, suggesting a potential accident.

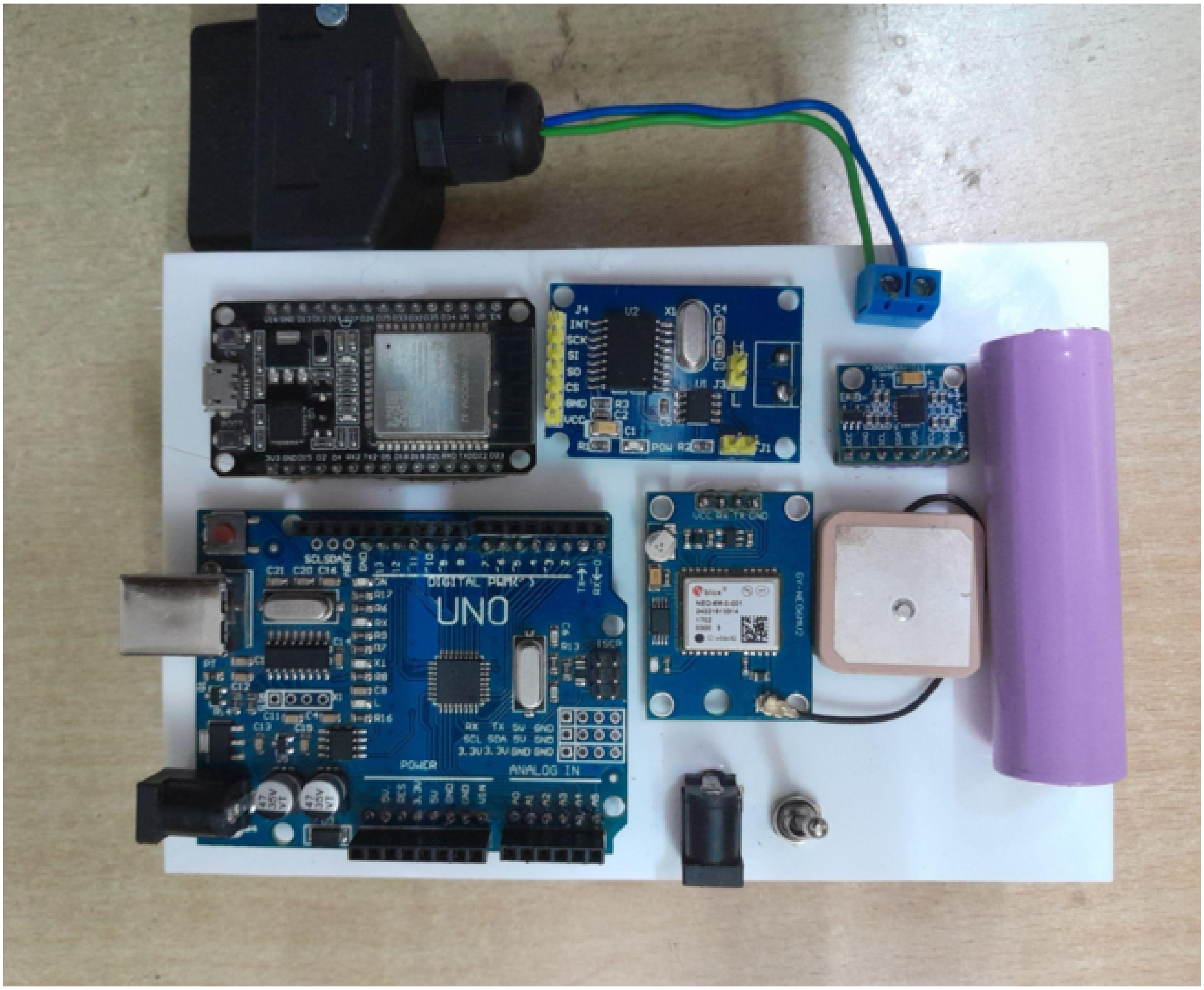

Figure 10: Vehicle Accident Detection and Advancement System (top view).

IV. RESULT

Central to the implementation of this work is the Arduino and ESP32 microcontrollers. The Arduino functions as the data aggregator, collating information from various sensors and interfacing with the car's OBD2 port. Subsequently, the ESP32 facilitates the transmission of this data to a connected mobile device. The accelerometer sensor assumes a pivotal role in monitoring vehicular dynamics, promptly detecting accidents and issuing notifications via the mobile application. In the event of an accident, an alarm sound is triggered, affording the user an opportunity to respond. Should the user fail to acknowledge the notification within a designated time frame, an alert message, inclusive of the vehicle's location, is dispatched to predetermined emergency contacts.

Moreover, the system empowers users to monitor their vehicle's real-time location and ascertain crucial parameters such as temperature, fuel levels, and engine status.

The system comprises two primary processes: accident detection and data acquisition from the vehicle's Electronic Control Unit (ECU). In the accident detection phase, a dedicated mobile application serves as the central interface. Leveraging the functionalities of our mobile application, we can effectively identify accidents and promptly dispatch alert messages to designated contacts. Additionally, the mobile application serves as a comprehensive platform for visualizing and accessing the entirety of the data obtained from the On-Board Diagnostics II (OBDII) port.

A. Accident Phase Implementation:

The accident phase is facilitated through the deployment of a mobile application developed using the Flutter framework. Initially, users are required to log in to the application, followed by the addition of a specific identification code corresponding to the prototype unit. Each prototype unit is assigned a unique verification code to ensure seamless integration with the mobile application. Subsequently, users are prompted to establish a connection with the ESP32 module via Wi-Fi, which serves as the conduit for transmitting data to the application.

Upon detection of an accident event (See Fig 11), the application triggers an alert notification, accompanied by an auditory cue. In the event of user intervention, wherein the alert message is acknowledged and closed, the notification is promptly dismissed. Conversely, if the user fails to respond within a predefined interval of 30 seconds, the system autonomously dispatches an alert notification to designated relatives, furnishing them with the precise location details.

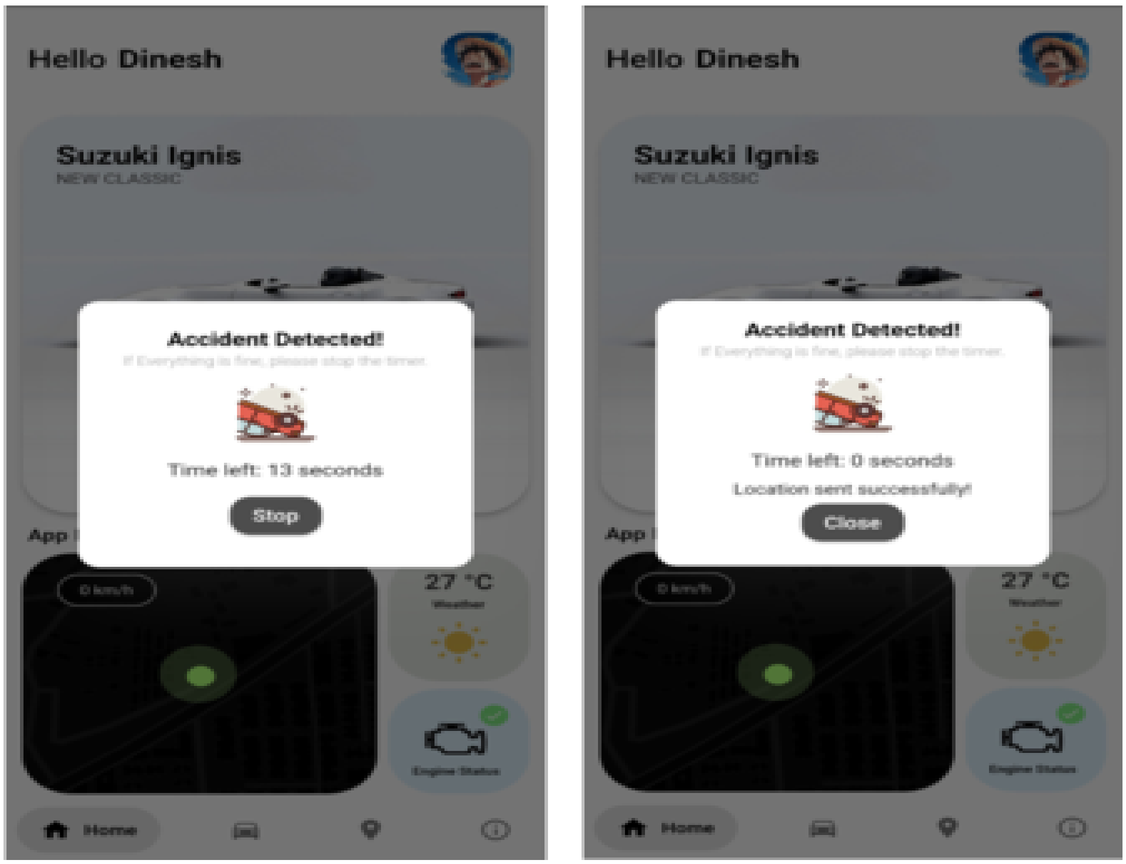

Figure 11: a. Accident detection popup in app screen, b. Sending location after 30 second.

B. Monitor Vehicle Information:

The application is additionally utilized for monitoring various data pertaining to the vehicles, encompassing parameters such as speed and location, in real-time. A dedicated page has been developed within the application interface to provide users with access to the vehicle's location and speed. Furthermore, distinct sections have been designated to display additional information concerning aspects such as lighting and engine status.

The mobile application contains the following activities:

1) Start and stop accident alert message.
2) Continue check for the accident situation.
3) Cancellation of alarm in the middle.
4) Continuously receive data from esp32.
5) Check the changes in any value and implement that in application.
6) Collect data of all sensors and use that to show all information in real time.

C. Testing:

For experimental validation, an XYZ car serves as the testbed to acquire data from the OBD-II port. Subsequently, the female OBD port within the vehicle is interconnected with the Arduino microcontroller via the IDE. Following the code upload process, the received RPM values are visualized in Figure 7, as depicted within the serial monitor interface.

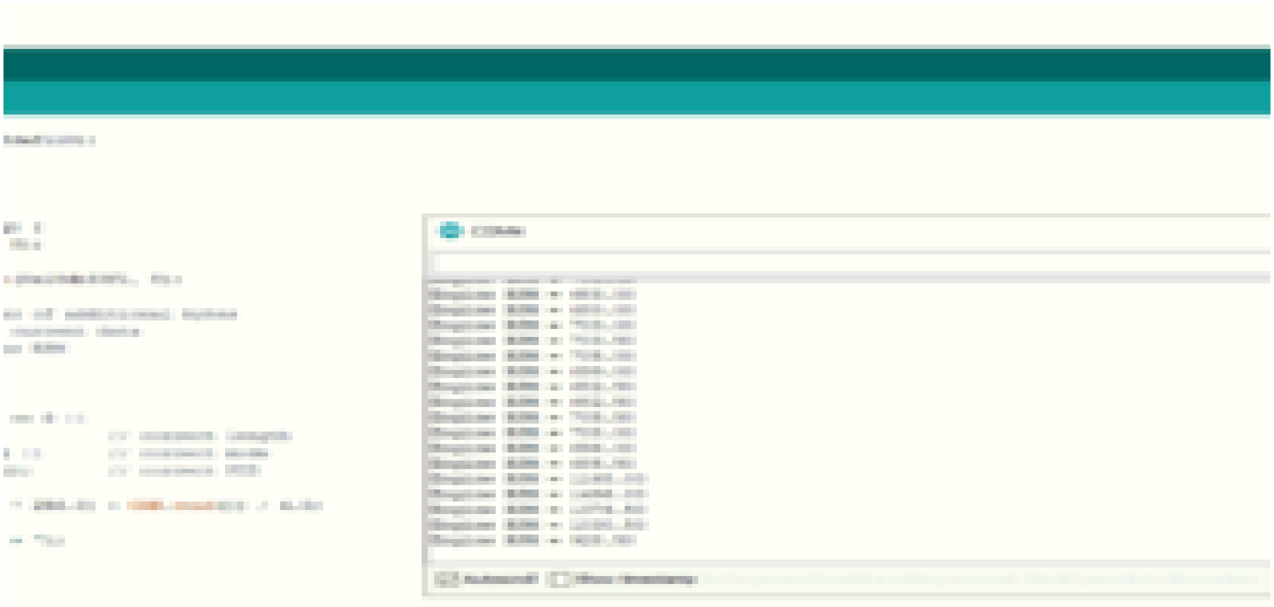

Figure 12: Reading RPM values with CAN communication..

In addition to RPM, this system has compiled a comprehensive dataset encompassing other metrics such as speed, engine status, and the like. Beyond employing CAN communication, rigorous testing of our accident detection sensor is conducted (See Fig 12). This entailed customizingthe code to a certain extent. Specifically, a slight modification of the threshold parameter from 180 to 20, thereby enhancing the sensor's sensitivity to minor alterations in vehicle dynamics. This adjustment proved instrumental, as evidenced by the present application's ability to detect accidents even in instances where vehicular motion changes are subtle.

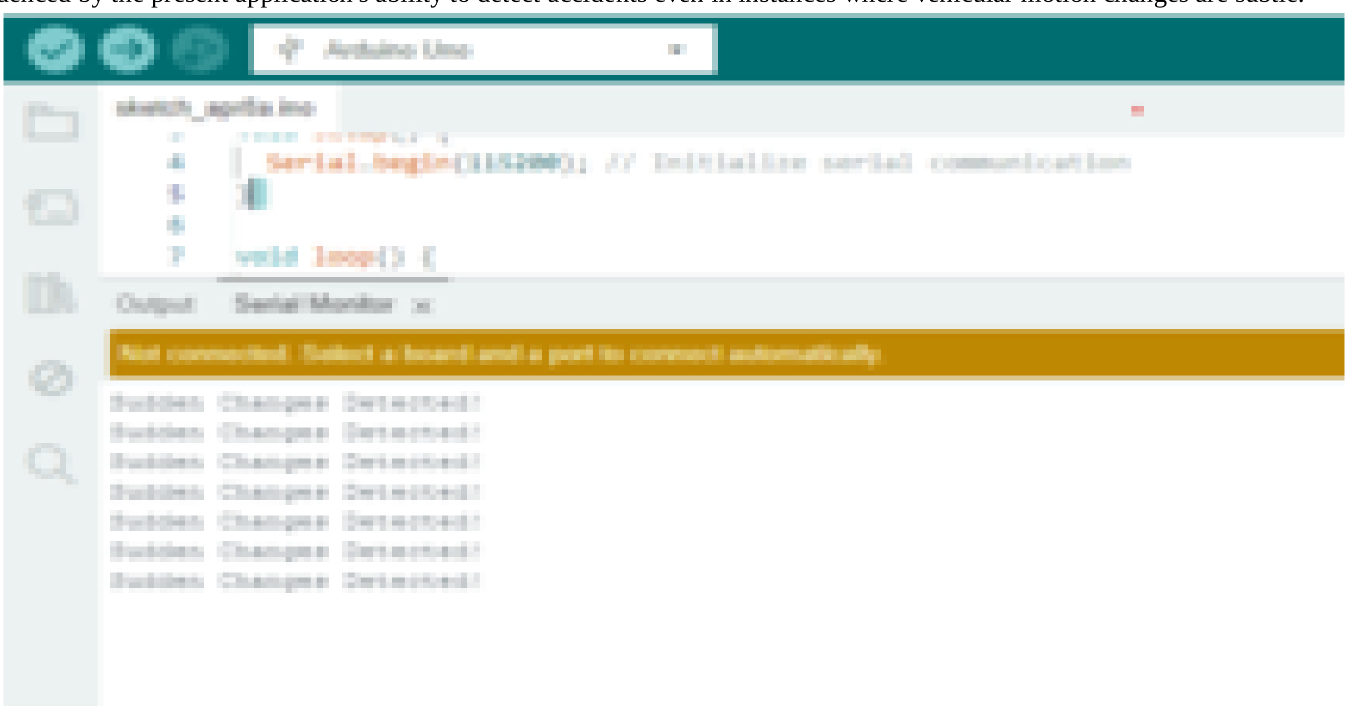

Figure 13: Testing acceleration sensor.

V. DISCUSSION

The findings stemming from our project, focused on the development of the VADAS, hold considerable significance within the realm of electronics, particularly in the realm of augmenting road safety. Through the integration of sensor technologies, including accelerometers and GPS modules, with microcontrollers, our endeavor contributes to the enhancement of safety protocols on roads.

A paramount aspect of this project entails the provision of timely warnings to drivers and their associates or emergency responders. By precisely discerning abrupt alterations in vehicle acceleration, our system is adept at initiating immediate alerts, thereby mitigating potential risks.

Furthermore, the integration of GPS technology facilitates the precise tracking of vehicle locations, thereby expediting response times and augmenting the efficacy of emergency interventions. This capability bears profound implications for saving lives and minimizing the severity of accidents.

Beyond its primary function of accident detection, our project boasts a versatile array of capabilities. It is adept at collecting comprehensive data from vehicles, encompassing metrics such as engine status, temperature, and system faults. This holistic approach enables proactive identification of issues, empowering users to address them effectively.

VI. CONCLUSION

The culmination of our research project, the Vehicle Accident Detection and Advancement System, holds the promise of serving as a lifesaving intervention for individuals involved in vehicular accidents. By virtue of its design and functionality, this system stands poised to play a pivotal role in mitigating accidents and augmenting overall road safety.One of the salient attributes of the proposed system is its intuitive interface, which renders it accessible to individuals irrespective of their technical acumen. Its user-friendly design ensures ease of operation, making it accessible even to non-technical users.

1) The accident detection sensor works perfectly when it detects some major changes in between normal driving behavior.
2) The CAN communication is also working properly, sending data to the application and all changes in real-time.
3) The app and the electronic device are communicating properly and sending and receiving data consistently over Wi-Fi communication.

In summary, the Vehicle Accident Detection and Advancement System represents a significant stride forward in the realm of road safety technology. Its capacity to expedite emergency response times, mitigate accident severity, and ultimately preserve lives underscores its indispensable role in contemporary transportation systems. With this system at our disposal, we are empowered to exercise comprehensive oversight over our vehicles, thereby fostering a safer and more secure vehicular environment.

VII. FUTURE ENHANCEMENT

The proposed system deals with collecting data from vehicles and detecting accidents. In future we would try to add more advanced sensors,and use advanced fusion algorithms with machine learning, for accurate results. These are the ideas that we want to implement in the future:

1) Reducing the size of the prototype.
2) Using a GSM module for communication over the internet instead of ESP-32.
3) Adding a two way CAN communication method for controlling the vehicle with mobile application.
4) Smart notification and emergency response coordination with emergency responders.
5) Integrating Human-Machine Interaction (HMI) with VADAS to enhance the user experience.
6) Using less power consuming hardware devices.

- Detecting fire: The system possesses the capability to detect fire through the default sensor of the vehicle by directly interfacing with the Electronic Control Unit (ECU) via Controller Area Network (CAN) communication. Moreover, it can accommodates the integration of additional fire sensors externally, thereby enhancing the precision and reliability of fire detection.
- Integration with Vehicle Telematics Systems: Also a possibility of upgradationof the present system to create a model that can interact and communicate with other vehicles. Using radio communication the system can communicates the nearby vehicles thereby sharing required information. It’s a V2V communication that can provide many advantages and solve many traffic problems.

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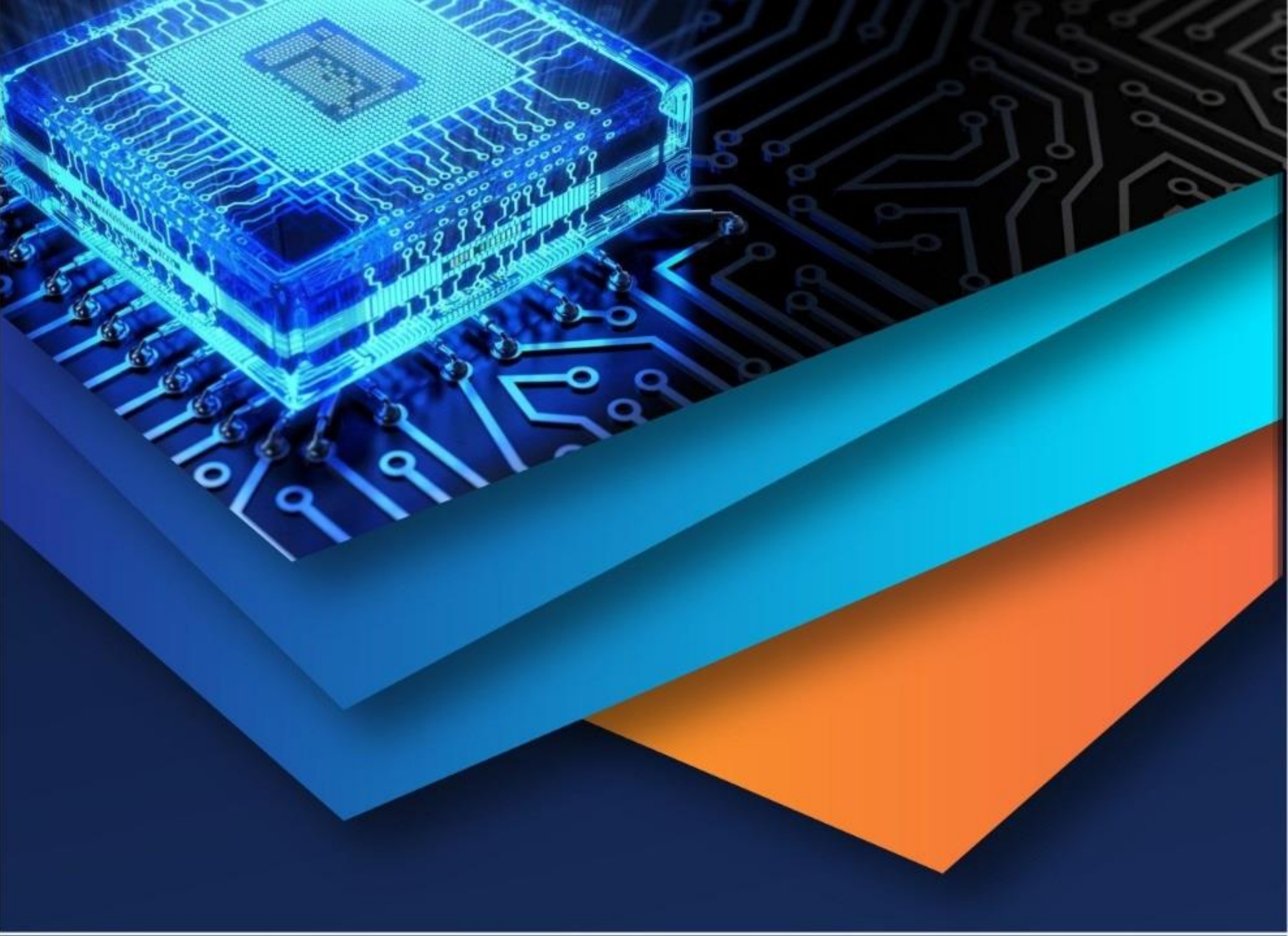

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