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IoT-Based Smart Helmet for Accident Detection and Emergency Alert System

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Abstract*—Road accidents involving two-wheeler riders are a major cause of injuries and fatalities due to delayed emergency response, improper helmet usage, and unsafe driving practices. This paper presents an IoT-Based Smart Helmet for Accident Detection and Emergency Alert System designed to enhance rider safety through intelligent monitoring and automated emergency communication. The proposed system integrates an IR sensor for helmet detection, an alcohol sensor for monitoring rider sobriety, an accelerometer sensor for accident detection, and GPS and ESP32-based IoT communication for real-time location tracking and emergency alert transmission.The system ensures that the vehicle can be operated only when the rider wears the helmet properly and is not under the influence of alcohol. In the event of an accident, the system automatically detects the impact and sends an emergency alert along with the rider's live location to registered contacts, enabling faster rescue operations and medical assistance. Initial prototype testing demonstrated the effectiveness of the system in monitoring rider safety conditions and supporting timely emergency notifications. The proposed solution is cost-effective, user-friendly, and suitable for real-world implementation.

Keywords — Smart Helmet, IoT, Accident Detection, GPS, GSM, Alcohol Detection, Rider Safety, Emergency Alert System, Real-Time Tracking.

I. INTRODUCTION

Road safety has become one of the major concerns in today's world due to the increasing number of road accidents and fatalities involving two-wheeler riders. Many accidents occur because riders do not wear helmets properly, drive under unsafe conditions, or fail to receive immediate medical assistance after an accident. Delayed emergency response and the lack of real-time accident detection systems often increase the severity of injuries and loss of life. Therefore, there is a growing need for intelligent safety solutions that can provide both preventive measures and instant emergency support for riders. In most real-world situations, accident victims are unable to communicate their condition or location immediately after a crash, especially in isolated or traffic-prone areas. Family members and emergency services may remain unaware of the accident for a long time, causing delays in rescue operations and medical treatment. Additionally, unsafe practices such as riding without a helmet or driving under the influence of alcohol further increase the risk of accidents. With the rapid growth of IoT technology, embedded systems, and wireless communication, smart safety devices have emerged as an effective solution for improving rider protection and accident management.

Recent advancements in IoT, sensor technology, and intelligent monitoring systems have enabled the development of automated accident detection and alert systems. Technologies such as GPS, GSM modules, vibration sensors, and alcohol sensors can be integrated into smart helmets to provide real-time monitoring and emergency communication. Unlike traditional safety measures, smart helmet systems can automatically detect accidents, track the rider's location, and send instant alerts to emergency contacts or medical services. The Smart Helmet Accident and Safety Alert System is designed to provide a practical and user-friendly solution for enhancing the safety of two-wheeler riders. The system combines hardware components and communication technologies to create an intelligent helmet capable of monitoring rider safety conditions in real time. By using sensors to detect helmet usage, alcohol consumption, and accident impacts, the system ensures that preventive safety measures are followed before and during travel. In emergency situations, the integrated GPS and GSM modules automatically share the rider's live location and alert messages with registered contacts, enabling quick medical assistance and reducing the chances of severe consequences.

II. LITERATURE REVIEW

A. Smart Helmet Systems for Rider Safety

Recent research shows a significant increase in the use of smart helmet technologies for improving road safety and reducing accident-related fatalities. Many studies focus on integrating IoT devices, sensors, and wireless communication systems into helmets to ensure rider protection and real-time monitoring.

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Smart helmet systems using sensors such as vibration sensors, IR sensors, and accelerometers are capable of detecting whether the rider is wearing the helmet properly and identifying accident situations with good accuracy. Some research works also include alcohol detection systems that prevent bike ignition if alcohol consumption is detected, helping in reducing accidents caused by drunk driving. These developments demonstrate how intelligent helmet systems can enhance rider safety through automated monitoring and preventive measures.

B. IoT-Based Accident Detection and Emergency Alert Systems

Artificial Intelligence and IoT technologies have transformed accident detection and emergency response systems by enabling faster communication and real-time tracking. Various studies on accident detection systems using GPS and GSM modules show that automatic alert generation can significantly reduce emergency response time after road accidents. These systems are designed to send the accident location and emergency messages directly to family members, hospitals, or emergency services without requiring manual intervention. Research also highlights the importance of real-time monitoring and wireless communication in improving rescue operations, especially in remote or traffic-prone areas where immediate medical support may not be available. However, challenges such as sensor accuracy, false alerts, and network dependency still remain important concerns in practical implementation. Many researchers have also focused on integrating accelerometers, gyroscope sensors, and vibration detection.
Furthermore, recent studies have explored the use of cloud-based platforms and mobile applications for storing accident data and providing real-time notifications.

C. Intelligent Monitoring and Safety Enhancement Using Embedded Systems

Beyond accident detection, embedded systems and intelligent monitoring technologies are widely used for improving overall transportation safety and rider behavior analysis. Several research studies focus on integrating microcontrollers, IoT platforms, and cloud-based monitoring systems to track rider activities and safety conditions continuously. Advanced smart helmet solutions are capable of monitoring helmet usage, vehicle ignition control, rider tracking, and environmental conditions in real time. Some systems also include features such as voice assistance, live location tracking, and mobile application integration for better user interaction and convenience. These advancements highlight the growing role of intelligent embedded systems in creating safer, smarter, and more reliable transportation environments for two-wheeler riders.

D. GPS and Real-Time Location Tracking for Rider Safety

Real-time location tracking plays a crucial role in modern smart transportation and emergency management systems. Many smart helmet solutions utilize GPS technology to continuously monitor the rider’s location and provide accurate tracking during emergency situations. In the event of an accident, the GPS module identifies the exact location of the rider and shares it instantly with family members, hospitals, or emergency services through GSM or IoT communication systems. This significantly reduces delays in rescue operations and improves the chances of providing timely medical assistance. Furthermore, GPS-based tracking enhances rider security, supports route monitoring, and enables efficient coordination between emergency responders and accident victims. These advancements demonstrate the importance of location-aware technologies in improving road safety and emergency response effectiveness.

III. KEY CONTRIBUTIONS OF THE PROPOSED SYSTEM

A. Real-Time Accident Detection and Emergency Alert

The proposed smart helmet continuously monitors the rider's condition using sensors and detects accident situations in real time. Whenever a serious accident occurs, the system automatically sends an emergency alert message along with the rider's current location to registered contacts. This helps in reducing rescue time and ensures that medical assistance can reach the victim as quickly as possible.

B. Integrated Rider Safety Monitoring System

Unlike traditional helmet safety solutions, the proposed system combines multiple safety features into a single platform. It monitors helmet usage, alcohol consumption, accident detection, and location tracking simultaneously. This integrated approach improves rider safety and provides a more reliable solution for accident prevention and emergency response.

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C. Solar-Powered and Cost-Effective Design

The system incorporates a solar panel to support its power requirements and improve energy efficiency. This reduces dependency on external charging and makes the helmet more suitable for long-term use. The overall design is simple, affordable, and practical, making it suitable for real-world implementation by a large number of two-wheeler riders. The use of readily available components helps in reducing the overall system cost while maintaining reliable performance. This combination of energy efficiency and affordability makes the proposed system a sustainable solution for enhancing rider safety and accident management.

IV. PROPOSED SYSTEM

The proposed Smart Helmet Accident and Safety Alert System is designed to improve the safety of two-wheeler riders by using IoT technology, sensors, and wireless communication modules. The system combines hardware and software components to monitor rider safety conditions in real time and provide immediate assistance during emergency situations. The smart helmet is equipped with sensors such as an alcohol sensor, accelerometer sensor, and helmet detection sensor to ensure safe riding practices. The system checks whether the rider is wearing the helmet properly and also detects alcohol consumption before allowing the vehicle to start.

During travel, the sensors continuously monitor abnormal conditions and accident impacts. If a serious accident occurs, the system automatically detects the collision and sends an emergency alert message along with the rider's live GPS location to registered contacts, nearby hospitals, or emergency services using the ESP32-based IoT communication system. The system also supports real-time location tracking and monitoring to improve rescue operations and reduce response time. By integrating intelligent monitoring, accident detection, and emergency communication into a single system, the proposed solution provides a reliable and efficient approach for enhancing road safety and reducing accident-related fatalities.

The proposed system is designed to operate automatically with minimal human intervention, ensuring greater reliability during emergency situations. By integrating intelligent sensing and communication technologies, the system continuously evaluates the rider's safety status and responds immediately when unsafe conditions are detected. The combination of accident detection, location tracking, and emergency notification helps reduce response time and improve the chances of timely medical assistance. This integrated approach makes the system suitable for enhancing road safety and protecting two-wheeler riders in real-world environments.

ADVANTAGES OF PROPOSED SYSTEM

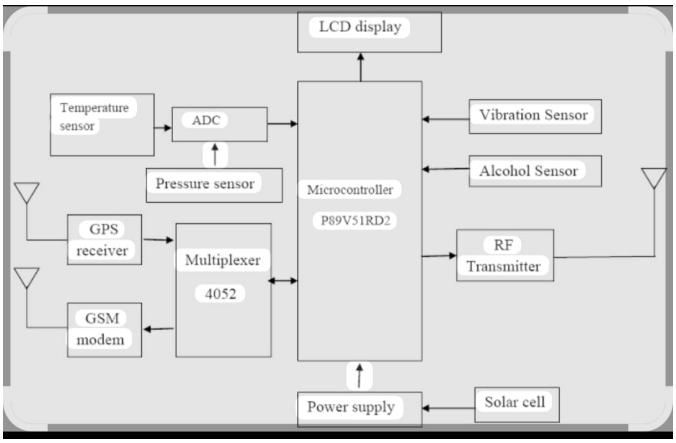
- Provides real-time accident detection and emergency alert facilities.
- Sends live GPS location to emergency contacts for faster rescue operations.
- Detects whether the rider is wearing the helmet properly before allowing vehicle ignition.
- Improves emergency response time by instantly notifying family members or medical services.
- Supports continuous monitoring of rider safety conditions during travel.

V. METHODOLOGY

The Smart Helmet Accident and Safety Alert System is developed using IoT technology, embedded systems, and wireless communication modules to enhance rider safety and provide emergency support during accidents. The system consists of a smart helmet integrated with sensors such as an alcohol sensor, accelerometer sensor, and helmet detection sensor, which continuously monitor the rider's safety conditions. The accelerometer sensor continuously detects sudden impacts, abnormal movements, and collision forces to identify accident situations in real time. Initially, the system checks whether the rider is wearing the helmet properly and verifies alcohol levels before allowing the vehicle to start. During travel, the accelerometer sensor continuously monitors sudden impacts, rapid changes in motion, and abnormal movements to detect accident situations accurately. If a serious accident is detected, the microcontroller processes the sensor data and activates the emergency alert mechanism. The GPS module identifies the rider's exact location, while the GSM module sends an alert message along with the live location to registered emergency contacts or nearby medical services. The system also supports real-time tracking and monitoring to improve rescue response time. By combining intelligent sensing, automated accident detection, and wireless communication, the proposedmethodology provides an efficient and reliable solution for improving road safety and reducing accident-related fatalities.

The overall architecture of the proposed model is illustrated in Fig. 5.1.

A. Overall Architecture



. Fig.5.1 Architecture of Smart Helmet for Accident and Safety Alert

B. Hardware Implementation

1) Alcohol Sensor

The alcohol sensor is used to detect the presence of alcohol in the rider's breath. If the alcohol level exceeds the predefined limit, the system prevents the vehicle from starting, helping to avoid drunk driving accidents.

2) Accelerometer Sensor

The accelerometer sensor detects sudden movements, vibrations, and impacts during accidents. It continuously monitors motion changes and helps in identifying accident situations in real time.

3) IR Sensor

The IR (Infrared) sensor is used to detect whether the rider is wearing the helmet properly. The bike ignition system is activated only when the helmet is worn correctly.

4) ESP32 Microcontroller

The ESP32 microcontroller acts as the main controller of the system. It processes sensor data, manages accident detection, acquires GPS location information, and transmits emergency alerts through Wi-Fi-based IoT communication.

5) GPS Module

The GPS module is used to track the real-time location of the rider. During an accident, it provides accurate latitude and longitude coordinates for emergency alerts and rescue operations.

6) Buzzer

The buzzer is used as an alert device to provide warning sounds during unsafe conditions, accident detection, or system notifications.

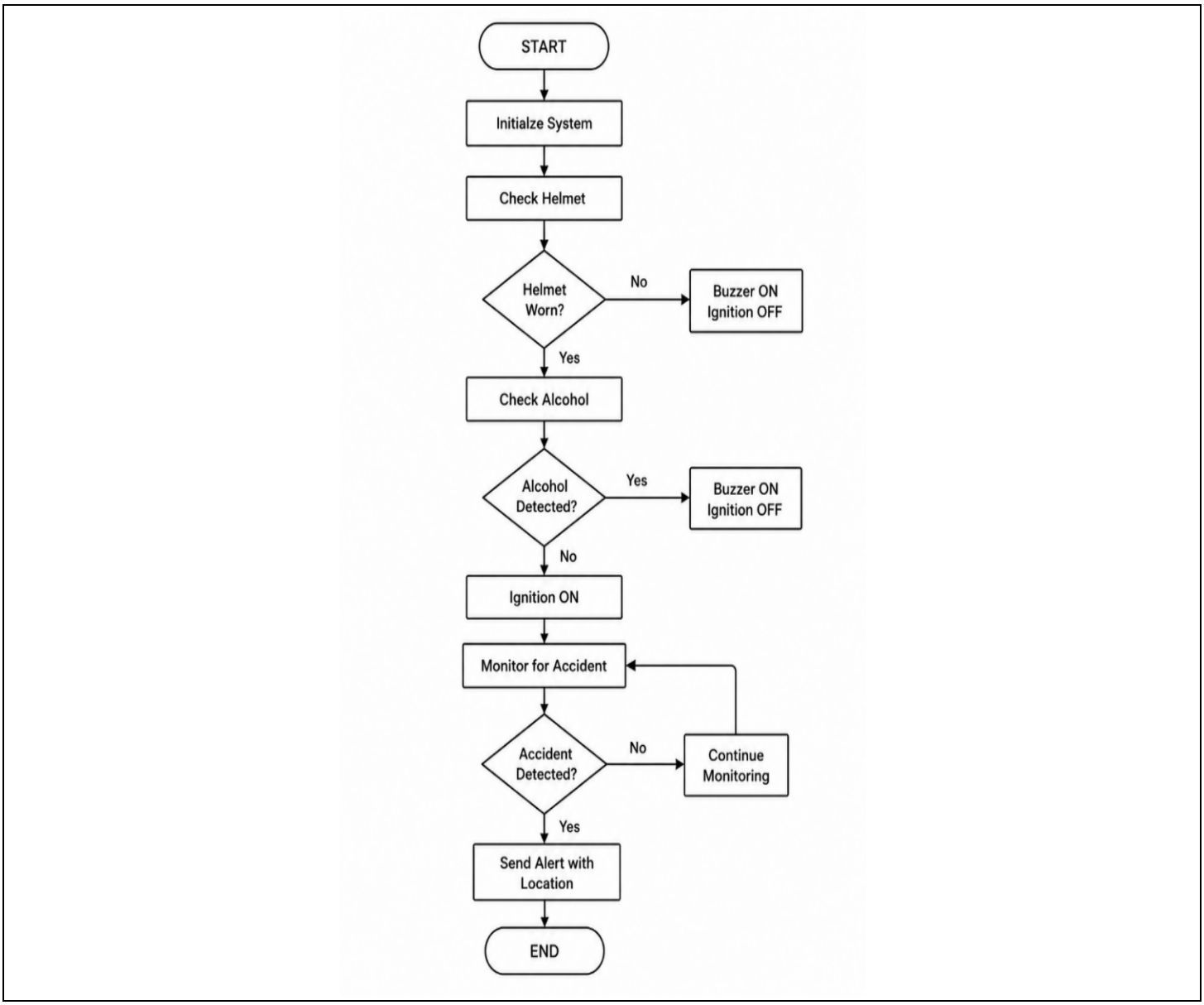
7) Relay Module

The relay module controls the bike ignition system electronically. It allows or blocks the engine start operation based on helmet usage and alcohol detection conditions.

8) Solar Panel

A 5V, 1W solar panel is used to generate electrical energy from sunlight and charge a 3.7V rechargeable Li-ion battery. The stored energy powers the ESP32, sensors, GPS, and communication modules, reducing dependence on external charging. This improves energy efficiency and makes the smart helmet suitable for long-term real-world use.

C. Flow Chart



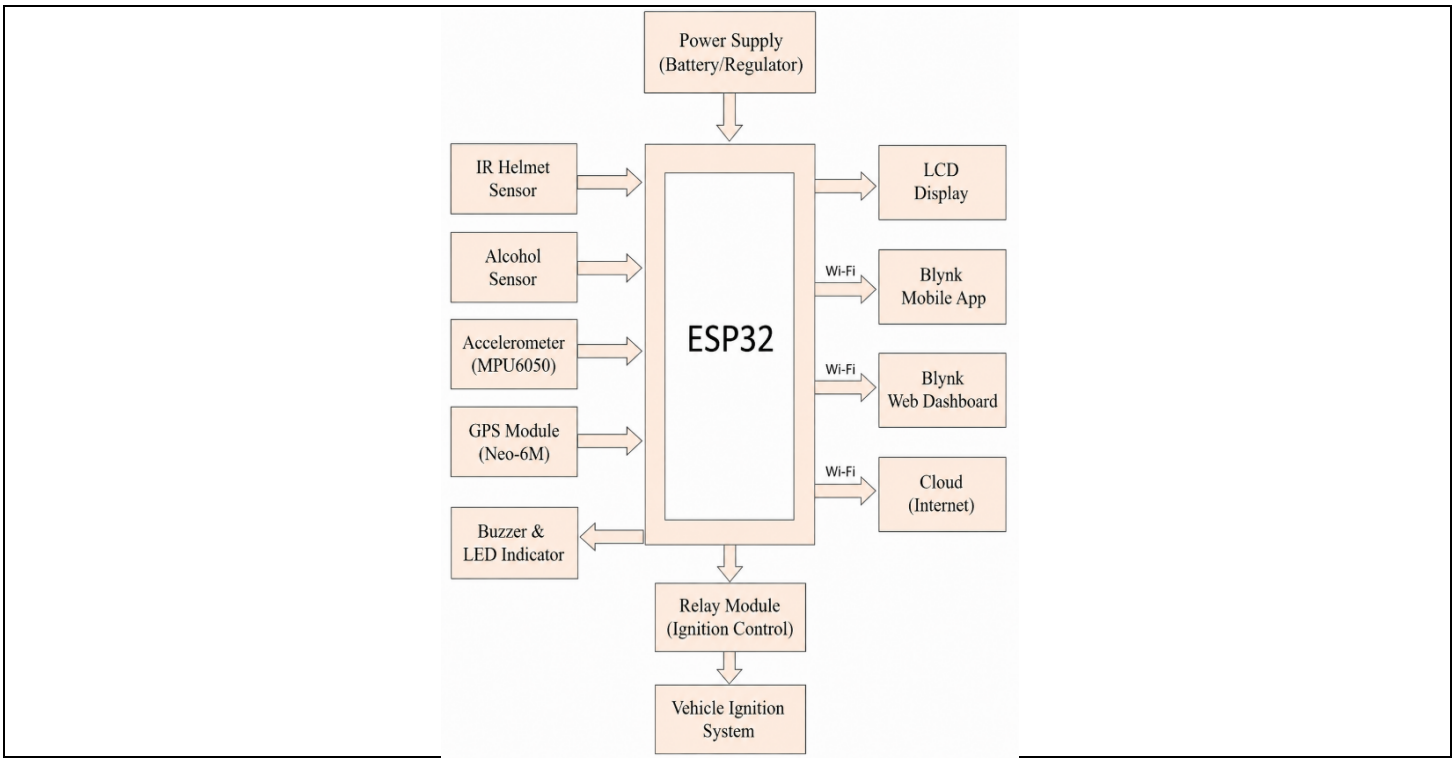
D. Software Implementation

The software implementation of the Smart Helmet Accident and Safety Alert System is developed using embedded programming, IoT communication, and real-time monitoring techniques. The software is programmed using Arduino IDE and uploaded to the ESP32 microcontroller. The software continuously reads data from various sensors such as the alcohol sensor, IR sensor, and accelerometer sensor to monitor the rider's safety conditions in real time.

Initially, the program checks whether the rider is wearing the helmet properly using the IR sensor and verifies alcohol levels through the alcohol sensor. If both conditions are safe, the relay module allows the bike ignition system to start. During the ride, the accelerometer continuously monitors sudden impacts, abnormal movements, or accident conditions. When an accident is detected, the software automatically activates the emergency alert process.

The GPS module collects the rider's current location coordinates, and the ESP module sends the accident alert message and live location details to registered emergency contacts or monitoring systems through wireless communication. The buzzer is also activated to provide immediate warning indications.

E. Block Diagram



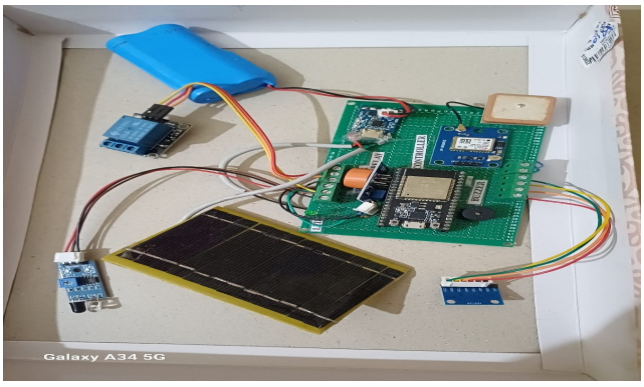
VI. RESULT ANDDISCUSSION

The Smart Helmet Accident and Safety Alert System was successfully designed and implemented using IoT technology, sensors, and wireless communication modules. The system effectively monitored rider safety conditions such as helmet usage, alcohol detection, and accident identification in real time. Initial prototype testing showed that the IR sensor accurately detected whether the rider was wearing the helmet properly, while the alcohol sensor successfully identified alcohol presence and prevented vehicle ignition under unsafe conditions.

The accelerometer sensor effectively detected sudden impacts and abnormal movements during accident situations. Once an accident was identified, the GPS module captured the rider's live location, and the ESP communication module transmitted emergency alert messages to registered contacts. The buzzer also provided immediate warning indications during emergency situations.

The overall system demonstrated reliable performance and efficient communication between hardware components. The integration of safety monitoring, accident detection, and emergency alert functionalities into a single smart system improved the effectiveness of rider protection and emergency response.

However, due to hardware and time constraints, extensive real-world testing and performance evaluation could not be performed. Future work will focus on evaluating the system using larger test datasets and measuring parameters such as detection accuracy, GPS precision, and alert delivery time.



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VII. FUTURE SCOPE

The Smart Helmet Accident and Safety Alert System can be further enhanced by integrating advanced technologies to improve safety, reliability, and user convenience. Future versions of the system can incorporate Artificial Intelligence and Machine Learning algorithms to improve accident detection accuracy, analyze rider behavior, and reduce false alerts. Integration with mobile applications and cloud platforms can enable real-time monitoring, data storage, and live location tracking for better emergency management.

Additional safety features such as voice assistance, automatic emergency calling, night vision support, camera-based monitoring, and obstacle detection can further enhance rider awareness and protection. Health monitoring sensors such as heart rate, body temperature, blood oxygen level, and fatigue detection sensors can also be integrated to continuously monitor the rider's physical condition and generate alerts during medical emergencies. These features can help prevent accidents caused by health-related issues and rider fatigue.

Advanced communication technologies such as 5G and IoT-based smart transportation networks can improve data transmission speed and emergency response efficiency. Integration with hospitals, ambulance services, and traffic management systems can help provide faster assistance during accident situations. These advancements can make the proposed system more intelligent, reliable, and suitable for large-scale deployment in modern road safety and smart transportation applications.

VIII. CONCLUSION

The Smart Helmet Accident and Safety Alert System was successfully developed to enhance the safety of two-wheeler riders by integrating IoT technology, sensors, and wireless communication modules. The system effectively monitors important safety conditions such as helmet usage, alcohol detection, and accident identification in real time. In case of an accident, the system automatically sends emergency alerts along with the rider's live location to registered contacts, helping to reduce delays in rescue operations and medical assistance.

The project demonstrates that the combination of intelligent monitoring systems and automated emergency communication can significantly improve road safety and reduce accident-related fatalities. The implemented system is reliable, cost-effective, user-friendly, and suitable for real-world applications. Overall, the proposed Smart Helmet Accident and Safety Alert System provides an efficient solution for accident prevention, rider protection, and emergency response, contributing toward safer and smarter transportation systems.

In addition to improving rider safety, the proposed system also promotes responsible driving behavior by ensuring that essential safety measures are followed before starting the vehicle. The integration of modern technologies such as GPS tracking, IoT communication, and sensor-based monitoring makes the system more intelligent and efficient compared to traditional safety methods. The successful implementation and testing of the project prove that smart safety solutions can play an important role in minimizing road accidents and saving human lives. With further improvements and advanced features, the system has strong potential for future development and large-scale adoption in smart transportation and road safety applications.

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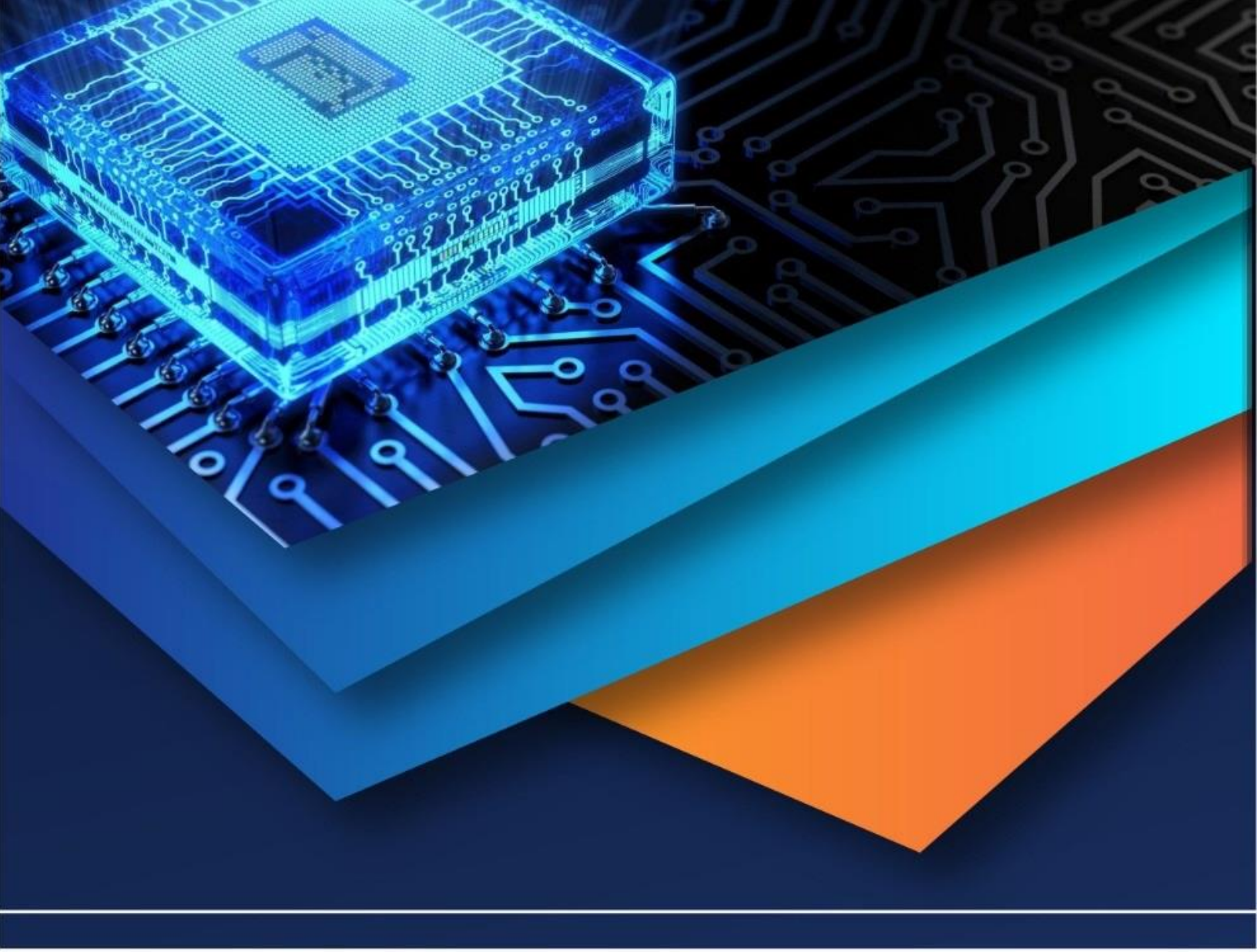

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