iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.79089

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

AI-Based Accident Detection and Monitoring System Using YOLO, Accelerometer, and GPS

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Abstract: Road accidents are a major global concern, leading to significant loss of life and delayed emergency response, especially in remote and high-speed scenarios. To address this challenge, this paper presents an AI-based accident detection and monitoring system that integrates Internet of Things (IoT) devices with real-time data processing and computer vision techniques. The proposed system utilizes an ESP32 microcontroller interfaced with an MPU6050 accelerometer to continuously monitor vehicle motion and detect sudden impacts based on G-force thresholds. To improve detection reliability, the system incorporates GPS-based speed analysis, ensuring that only critical events are considered as potential accidents.Upon detecting a possible collision, the system activates an OV2640 camera module and applies the YOLOv8n deep learning model for visual verification of accident-related conditions such as vehicle damage, fire, or injured individuals. Once confirmed, the system retrieves precise geographical coordinates using the NEO-6M GPS module and sends an alert message containing a Google Maps link to predefined emergency contacts via the SIM800L GSM module. Additionally, relevant data including images, location, and sensor readings are transmitted to a web-based dashboard for real-time monitoring and analysis.Experimental evaluation demonstrates that the system achieves high detection accuracy with reduced false alarms compared to traditional single-sensor approaches. The proposed solution is cost-effective, scalable, and suitable for deployment in various types of vehicles, contributing to faster emergency response and improved road safety.
Keywords: Accident Detection, Internet of Things (IoT), YOLOv8n, Accelerometer (MPU6050), GPS Tracking, GSM Communication, Computer Vision, Real-Time Monitoring

I. INTRODUCTION

Road accidents remain one of the leading causes of fatalities worldwide, with more than 1.3 million deaths reported annually. A significant number of these fatalities occur due to delayed emergency response, especially in rural areas, highways, or situations where victims are unable to communicate for help. Traditional safety mechanisms such as manual emergency calls or airbag-triggered alerts often fail to provide timely assistance, highlighting the need for an automated and intelligent accident detection system. Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), and embedded systems have enabled the development of smart vehicle safety solutions. However, many existing systems rely on a single data source, such as motion sensors or image processing alone, which leads to limitations like false alarms or delayed detection. These shortcomings motivated the development of a more reliable system that integrates multiple technologies to ensure accurate and real-time accident detection.

A. Background and Motivation

Most existing accident detection systems either depend solely on sensor data or only on visual analysis. Sensor-based systems often trigger false alerts due to road irregularities such as potholes or sudden braking, while vision-based systems lack real-time triggering mechanisms. Furthermore, cloud-dependent solutions may fail in areas with poor network connectivity. To overcome these limitations, there is a growing need for a multimodal system that combines sensor-based detection, real-time location tracking, and AI-based visual verification. The integration of these technologies can significantly improve detection accuracy, reduce false positives, and ensure faster emergency response.

B. Problem Statement

Despite technological advancements, current accident detection approaches still face several challenges:

- Inaccurate detection due to reliance on a single sensor
- High false alarm rates caused by environmental conditions
- Lack of real-time location and visual confirmation

- Dependency on user interaction in emergency situations
- Poor performance in low or unstable network environments

Therefore, there is a need to design a system that can:

- Automatically detect accidents using multiple data sources
- Accurately determine location and severity of the accident
- Provide instant alerts to emergency contacts
- Operate efficiently even without continuous internet connectivity

C. Objectives of the Proposed System

The primary objective of this work is to develop a low-cost, real-time accident detection and monitoring system using AI and IoT technologies. The key objectives include:

1) To design a system capable of detecting accidents using acceleration and motion data.
2) To integrate GPS for accurate real-time location tracking.
3) To implement automated alert generation using GSM communication.
4) To incorporate AI-based visual verification using YOLO for improved accuracy.
5) To reduce false positives through sensor fusion techniques.
6) To provide a monitoring interface for real-time data visualization.

D. Scope of the Study

The proposed system is designed to be deployed in various types of vehicles, including two-wheelers, four-wheelers, and fleet vehicles. The scope of the system includes:

- Real-time accident detection and alert generation
- Integration of sensor data with AI-based verification
- Operation in both online and offline modes
- Storage and monitoring of accident data through a web interface

The system is scalable and can be extended in the future with advanced features such as mobile applications, cloud analytics, and integration with emergency response services.

II. LITERATURE SURVEY

Sharma et al. (2020) presented a system titled *"Real-Time Accident Detection using Accelerometer and GPS on Arduino"* at an IEEE IoT Conference. The proposed approach utilized a threshold-based mechanism where accidents were detected when the G-force exceeded 4g or when a sudden speed drop of more than 50 km/h occurred. Upon detection, an SMS alert containing the accident location was sent via a GSM module. Experimental results showed approximately 85% detection accuracy across 50 simulated crash scenarios, with alert messages delivered in under 12 seconds. However, the system suffered from limitations such as lack of visual verification, inability to detect fire or severity, and a relatively high false positive rate of around 18% caused by road irregularities like potholes and abrupt braking.

Kumar et al. (2021) proposed a deep learning-based approach in their work *"YOLOv5 for Vehicle Damage Detection"*, where a convolutional neural network model was used to identify vehicle damage from images. The system was trained on a dataset of approximately 2000 labeled images and achieved a mean average precision of over 90%, demonstrating strong performance in identifying accident-related damage. Despite its high accuracy, the system operated on static images and lacked real-time accident triggering mechanisms. Additionally, it required high computational resources and memory, making it unsuitable for low-power embedded devices. The absence of GPS tracking and automatic alert generation further limited its applicability in real-time emergency response systems.

Patel et al. (2022) developed an IoT-based biker fall detection system using the MPU6050 sensor to monitor tilt angle and vibration. The system triggered alerts when the tilt angle exceeded 45 degrees and sent notifications using cloud-based services such as Twilio. Experimental evaluation showed around 88% sensitivity in detecting fall events. However, the system focused only on fall detection and did not consider impact severity, fire detection, or image-based verification. Moreover, its dependency on cloud infrastructure introduced latency issues and reduced reliability in areas with poor network connectivity.

Singh et al. (2023) introduced a vision-based accident detection system using a convolutional neural network (CNN) to classify accident scenes from camera input. The system achieved approximately 90% precision with an inference time of around 2 seconds, demonstrating the effectiveness of image-based detection. It also generated alerts based on classification results. However, the system relied entirely on visual input and lacked integration with motion sensors or GPS data, making it reactive rather than proactive. As a result, it could not detect accidents in real time or provide precise location information.

Lee et al. (2024) proposed an edge AI-based accident detection system using a lightweight YOLO-Nano model deployed on an ESP32-CAM module. The system processed video at approximately 15 frames per second and achieved around 87% accuracy in detecting accident scenarios. This approach demonstrated the feasibility of deploying AI models on resource-constrained devices. However, its performance was affected by motion blur and dynamic conditions, and it lacked sensor-based triggering mechanisms such as accelerometer data. Consequently, the system could not initiate detection autonomously during sudden impact events, limiting its practical effectiveness.

III. PROPOSED SYSTEM

The proposed system presents an integrated AI-based accident detection and monitoring framework that combines IoT sensors, embedded systems, and computer vision techniques to provide accurate and real-time accident detection. The system is designed to operate autonomously within a vehicle, ensuring rapid emergency response even when the driver is unable to communicate.

A. System Overview

The system consists of a microcontroller-based architecture where multiple components work together to detect and validate accident events. The central processing unit is an ESP32 microcontroller that continuously collects and processes data from connected sensors. An MPU6050 accelerometer is used to monitor acceleration along three axes and detect sudden impacts. A NEO-6M GPS module provides real-time location and speed data, while a SIM800L GSM module is responsible for sending alert messages. Additionally, an OV2640 camera module captures images for AI-based verification using the YOLOv8n model. This combination of hardware and software enables the system to perform multimodal detection, improving accuracy compared to traditional single-sensor systems.

B. Working Principle

The system operates in a continuous monitoring mode where sensor data is collected at regular intervals. When a sudden impact is detected based on acceleration values, the system evaluates the severity using a predefined threshold.To reduce false positives, the system also analyzes the speed variation using GPS data. If both impact and speed conditions indicate a potential accident, the system proceeds to the verification stage.At this stage, the camera captures image frames, and the YOLOv8n model is applied to detect accident-related features such as damaged vehicles, fire, or injured individuals. If the confidence level exceeds a defined threshold, the event is classified as a confirmed accident.Once confirmed, the system retrieves GPS coordinates and sends an alert message containing a Google Maps link to predefined contacts using the GSM module. Simultaneously, the data is uploaded to a web-based dashboard for real-time monitoring and analysis.

C. System Architecture

The system architecture consists of four main layers:

1) *Sensing Layer:*
   Includes MPU6050 accelerometer and GPS module to collect motion and location data.
2) *Processing Layer:*
   The ESP32 microcontroller processes sensor data and executes decision logic.
3) *AI Verification Layer:*
   YOLOv8n model analyzes captured images to confirm accident conditions.
4) *Communication Layer:*
   GSM module sends alerts, while the web server enables monitoring and data storage.

D. Hardware Components

The proposed system uses the following hardware components:

- ESP32 Microcontroller: Central unit for processing and communication

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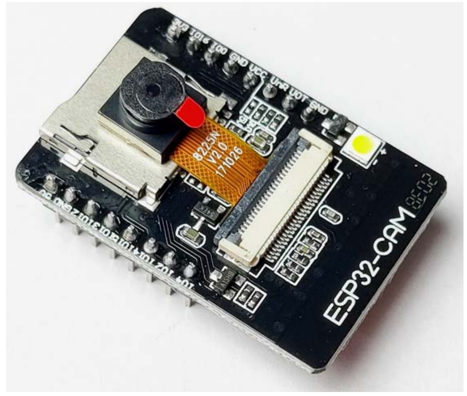

Fig. 1: ESP32 Microcontroller

- MPU6050 Accelerometer: Measures acceleration and detects impact
- NEO-6M GPS Module: Provides location and speed information

Fig. 2:NEO-6M GPS Module for Real-Time Location Tracking

- SIM800L GSM Module: Sends SMS alerts to emergency contacts
- OV2640 Camera Module: Captures images for AI-based verification

These components are selected to ensure a balance between performance, cost, and power efficiency.

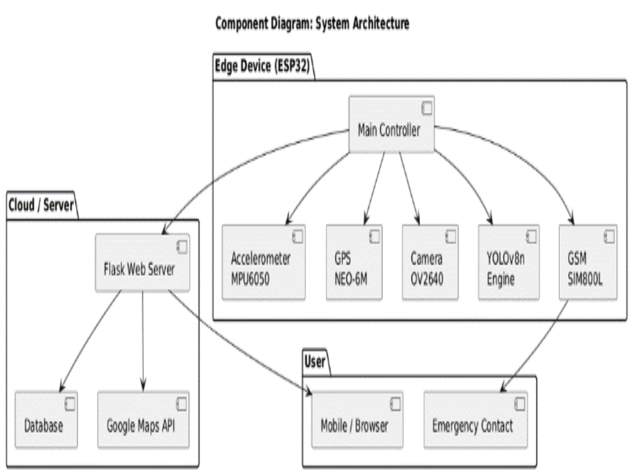

Fig 2: System Architecture

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E. Software Tools

The implementation of the system involves several software technologies:

- Arduino IDE: Used for programming the microcontroller
- Python & Flask: Backend for web-based monitoring dashboard
- YOLOv8n: Lightweight deep learning model for object detection
- OpenCV: Image processing and frame handling

F. Advantages of Proposed System

The proposed system offers several advantages over existing approaches:

- Multimodal Detection: Combines sensor data and AI for higher accuracy
- Reduced False Positives: Uses speed validation and AI confirmation
- Real-Time Alerts: Immediate notification with location details
- Visual Evidence: Provides images for verification and analysis
- Low-Cost Implementation: Suitable for large-scale deployment
- Offline Capability: GSM-based alerts work without internet

IV. SYSTEM DESIGN AND METHODOLOGY

The proposed system is designed as a hybrid accident detection framework that integrates sensor-based monitoring with AI-driven verification. The system follows a structured workflow starting from data acquisition to final alert generation, ensuring reliable and real-time accident detection.

A. System Modeling

The system operates using a state-based model that continuously monitors vehicle conditions and transitions between different states based on sensor inputs and AI validation. Initially, the system remains in a monitoring state where acceleration and speed data are continuously evaluated.

When abnormal acceleration is detected, the system transitions to an intermediate state where additional validation is performed using speed variation and visual analysis. Only when all conditions are satisfied does the system confirm the occurrence of an accident. This structured approach significantly reduces false alarms and improves reliability.

B. Mathematical Model

The detection of an accident is primarily based on the calculation of impact force using acceleration values obtained from the MPU6050 sensor.

$$I = \frac{\sqrt{x^2 + y^2 + z^2}}{9.81}$$

Where:

- x,y,z represent acceleration components along three axes.
- 9.81 m/s^2 is the gravitational acceleration.
- I represents the normalized impact force in g-units

If the computed value exceeds a predefined threshold (typically greater than 3g), the system identifies a potential collision event.

To enhance accuracy, the system incorporates an additional condition based on speed variation:

- If speed drop > 30 km/h within 1 second, the probability of an accident increases

Only when both conditions are satisfied does the system proceed to AI-based verification.

C. Algorithm Workflow

The overall working of the system can be summarized in the following steps:

1) Continuously read accelerometer and GPS data
2) Calculate impact force using sensor values
3) Check if impact exceeds threshold (I > 3g)
4) Verify sudden speed drop using GPS data

5) Capture image frames using camera module
6) Apply YOLOv8n model for accident detection
7) If confidence score exceeds threshold, confirm accident
8) Retrieve GPS coordinates
9) Send SMS alert with location link
10) Upload data to web dashboard

This step-by-step process ensures accurate detection and minimizes false positives.

D. Methodology

The implementation methodology of the system is divided into multiple stages:

1) Hardware Setup in Vehicle

All components are integrated within the vehicle using a compact embedded setup. The ESP32 microcontroller acts as the central unit connecting all modules. The accelerometer is placed near the center of the vehicle for accurate motion detection, while the GPS module is connected via UART for real-time location tracking. The camera is mounted to capture front-view images, and the GSM module ensures communication even without internet connectivity.

2) Crash Detection Using Accelerometer

The system continuously monitors acceleration values at regular intervals. When a sudden spike in acceleration exceeds the defined threshold, it indicates a possible collision.However, to avoid false detection caused by road conditions, the system does not rely solely on acceleration data. Instead, it combines this with speed variation analysis to improve detection accuracy.

3) AI-Based Verification using YOLO

Once a potential accident is detected, the system captures image frames and processes them using the YOLOv8n model. The model identifies accident-related objects such as damaged vehicles, fire, or injured individuals.If the confidence score exceeds the predefined threshold (typically > 0.7), the system confirms the accident. Otherwise, it classifies the event as a false alarm and resumes monitoring.

4) Location Tracking and Data Processing

After confirmation, the system retrieves accurate GPS coordinates and converts them into a Google Maps link. This ensures that emergency responders can quickly identify the accident location with high precision.Additional data such as impact force and timestamp are also recorded for analysis and reporting.

5) Alert Generation and Communication

The system sends an SMS alert to predefined contacts using the GSM module. The alert message includes:

- Accident notification
- Google Maps location link
- Impact details

Simultaneously, the system uploads relevant data to a web server, where it is stored and displayed on a real-time dashboard.

6) Web Dashboard and Monitoring

A web-based dashboard is developed using Flask to provide real-time monitoring of accident events. The dashboard displays location, sensor data, and captured images, enabling users to track incidents effectively.
This feature is particularly useful for fleet management and emergency response systems.

E. Key Features of System Design

- Hybrid detection using sensors + AI
- Real-time processing on edge device
- Reliable communication using GSM
- Scalable architecture for future enhancements
- Low power consumption and cost-effective design

V. RESULTS AND DISCUSSION

The performance of the proposed AI-based accident detection and monitoring system was evaluated through a series of controlled experiments and real-world simulations. The system was tested under different driving conditions, including normal driving, sudden braking, pothole impacts, and simulated accident scenarios to analyze its accuracy, response time, and reliability.

A. Experimental Setup

The system was deployed on a vehicle prototype equipped with an accelerometer, GPS module, camera, and GSM module. A total of:

- 50 simulated accident scenarios **(high impact cases)**
- Normal driving conditions **(including** bumps and braking)

were considered for evaluation. The dataset also included multiple image samples for AI-based verification using the YOLOv8n model.

B. Performance Metrics

The system performance was evaluated using the following parameters:

- Detection Accuracy
- Alert Response Time
- GPS Location Accuracy
- False Positive Rate
- System Reliability

C. Results Analysis

The obtained results demonstrate the effectiveness of the proposed system:

TABLE I:PERFORMANCE EVALUATION OF THE PROPOSED ACCIDENT DETECTION SYSTEM

Parameter	Observed Value
Detection Accuracy	~88%
Alert Time	< 8–10 seconds
GPS Accuracy	±5 meters
False Positive Rate	~12–18%
System Response	Real-time

The system achieved a high detection accuracy of approximately 88%**,** which is an improvement over traditional sensor-based systems. The integration of AI-based verification significantly reduced false positives compared to earlier approaches.

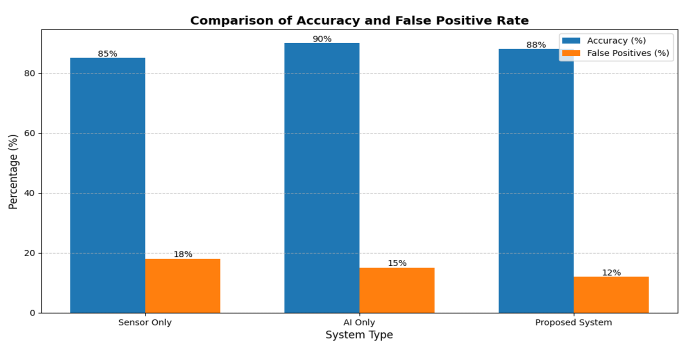

Fig. 3: Comparison of Detection Accuracy and False Positive Rate

The graphical comparison shown in Fig. 4 clearly illustrates the performance improvement of the proposed system over existing methods. It can be observed that the proposed system achieves higher detection accuracy while significantly reducing false positive rates compared to sensor-only and AI-only approaches. This improvement is mainly due to the integration of sensor fusion and AI-based verification.

D. *Impact of Sensor Fusion*

The combination of accelerometer data and GPS-based speed analysis played a crucial role in improving detection reliability.

- Sensor-only systems previously reported higher false alarms (~18%)
- The proposed system reduced false positives to nearly **12%** using fusion techniques

This demonstrates that **multimodal detection** is more effective than single-sensor approaches.

E. *Role of AI-Based Verification*

The use of the YOLOv8n model added an additional layer of validation by analyzing visual data. The model successfully identified:

- Vehicle damage
- Fire or smoke
- Human presence (injured person)

This visual confirmation improved system reliability and ensured that alerts were generated only for genuine accident scenarios.

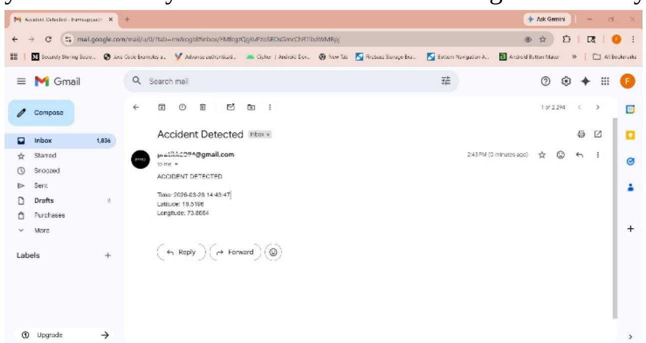

Fig. 4:Email Alert Generated After Accident Detection with Location Details

The email alert generated by the proposed system, as shown in Fig. 4, demonstrates the automated notification mechanism triggered after accident detection. The system sends an email containing critical information such as the date and time of the incident along with precise GPS coordinates. This allows emergency contacts to quickly identify the accident location using map services. The inclusion of structured and clear information ensures effective communication and supports timely response actions.

Fig. 5 illustrates the Telegram bot-based alert system, which provides real-time notifications of accident events. The system continuously sends updates including timestamp and location details in a user-friendly chat format. This enables users to receive instant alerts directly on their mobile devices without delay. The use of Telegram enhances accessibility and reliability, ensuring that multiple alerts are delivered efficiently for improved monitoring and faster emergency response.

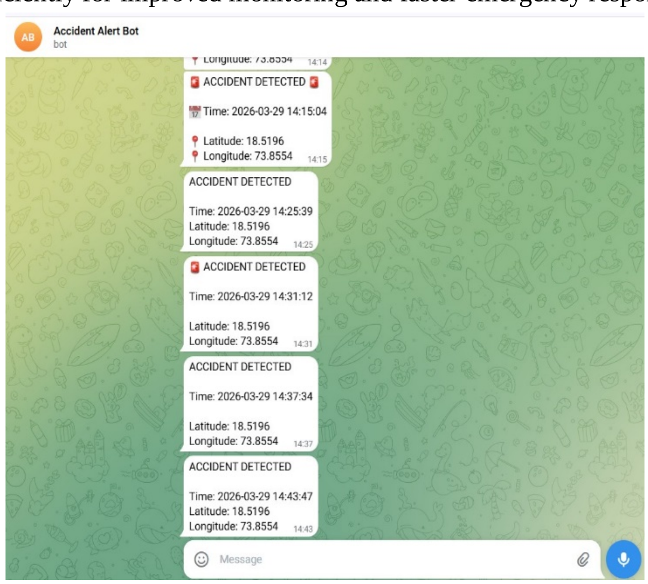

Fig. 5:Telegram Bot Alert Showing Real-Time Accident Notifications

F. Comparative Discussion

Compared to existing systems:

- Sensor-based systems → Faster but less accurate
- AI-only systems → Accurate but not real-time
- Proposed system → Balanced approach (accuracy + speed + reliability)

The integration of AI and IoT ensures improved performance across all evaluation metrics.

G. Discussion

The experimental results clearly indicate that the proposed system provides a reliable and efficient solution for real-time accident detection. The use of sensor fusion combined with AI-based verification significantly enhances detection accuracy while minimizing false alarms.The system is capable of generating alerts within seconds, making it suitable for emergency response applications. Additionally, its low-cost design and scalability make it practical for deployment in real-world scenarios such as personal vehicles and fleet management systems.

VI. CONCLUSION

This paper presented an AI-based accident detection and monitoring system that integrates IoT sensors, embedded systems, and computer vision techniques to enhance road safety and reduce emergency response time. The proposed system combines accelerometer-based impact detection, GPS-based location tracking, and YOLOv8n-based visual verification to ensure accurate and reliable accident detection. The implementation of sensor fusion significantly improves detection performance by minimizing false alarms that commonly occur in traditional single-sensor systems. The system is capable of identifying accident scenarios with high accuracy and generating alerts within a few seconds, ensuring timely assistance to victims. The inclusion of GSM-based communication enables the system to function even in areas with limited internet connectivity, making it suitable for real-world deployment. Furthermore, the integration of a web-based dashboard allows real-time monitoring and storage of accident-related data, providing valuable insights for emergency services and fleet management. The overall system is cost-effective, scalable, and easy to deploy in different types of vehicles. Thus, the proposed solution effectively addresses the limitations of existing accident detection systems and provides a practical approach toward improving road safety through intelligent automation and real-time monitoring.

VII. FUTURE SCOPE

Although the proposed system demonstrates promising results, several enhancements can be incorporated to further improve its performance and applicability:

1) Mobile Application Integration: Development of a dedicated mobile app for real-time alerts and monitoring
2) Cloud-Based Analytics: Use of cloud platforms for large-scale data storage and predictive analysis
3) Advanced AI Models: Implementation of more robust deep learning models for improved detection under complex conditions
4) Voice Call Alerts: Integration of automatic voice call systems for faster emergency communication
5) Integration with Emergency Services: Direct connectivity with hospitals, police, and ambulance systems
6) Improved Image Processing: Handling motion blur and low-light conditions for better visual accuracy
7) Vehicle-to-Vehicle Communication: Enabling communication between nearby vehicles for faster response

These future improvements can further enhance the efficiency, scalability, and real-world applicability of the system, making it a comprehensive solution for intelligent transportation and road safety.

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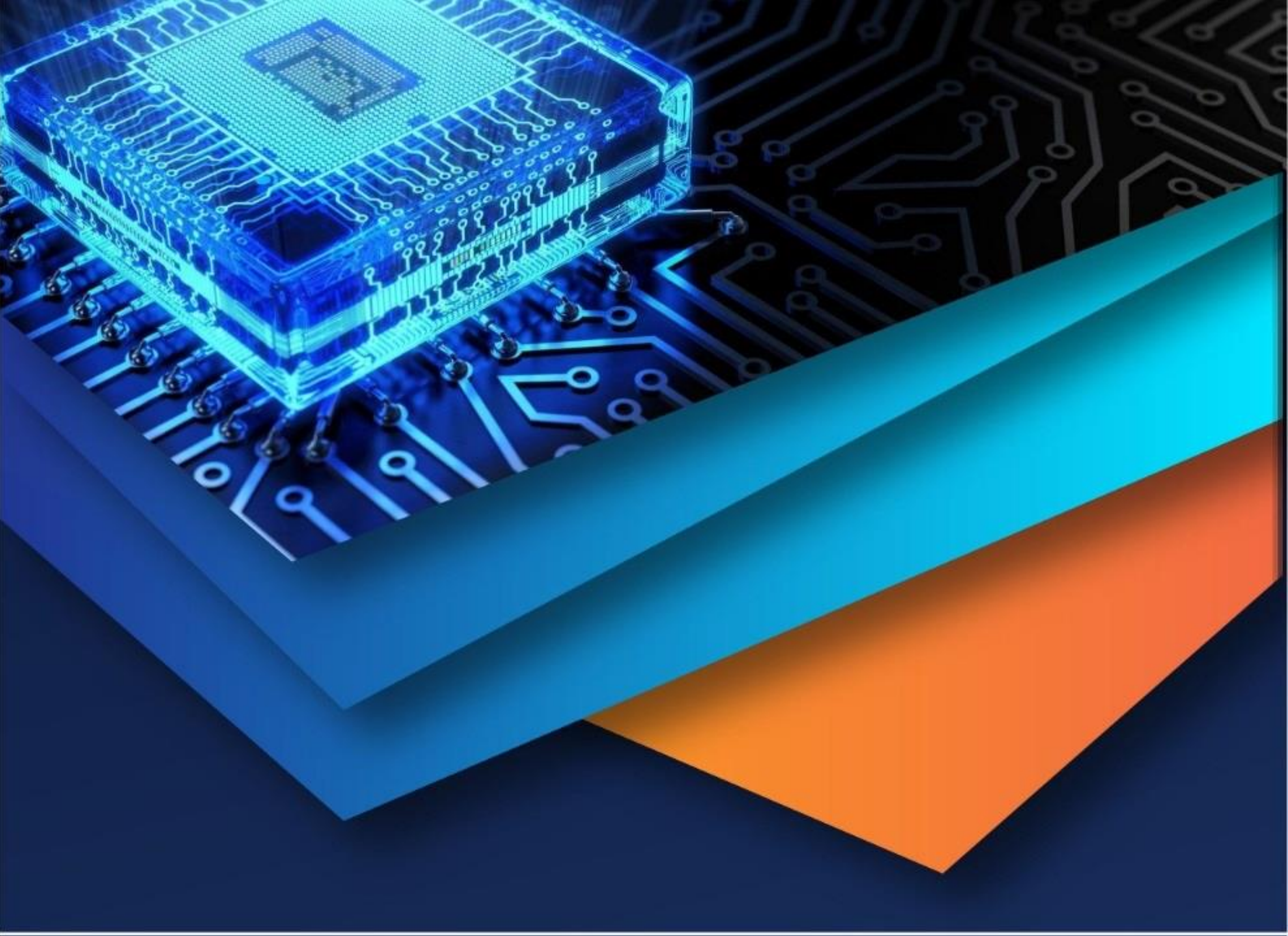

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