Raspberry Pi–Enabled Collision Alert System for Enhanced Night-Time Highway Safety

Dr. K.V. Vara Prasad[1], P. Navya Sree[2], P. Balaji[3], Y. Lavanya[4], G. Harshitha[5], A. Ganitha[6]

[1,2,3,4,5,6]Department of Electronics and Communication Engineering
Aditya College of Engineering
(Approved by AICTE and Affiliated to JNTUA, Anantapuramu & Accredited by NAAC A+ Grade)
Punganur Road, Madanapalle – 517 325, Andhra Pradesh, India.

Abstract*:* Driving on a highway at night is more dangerous because visibility is limited and unexpected hazards, such as animals or other obstructions, may appear on the road. The aim of this project is a robotic collision warning system prototype using a Raspberry Pi to improve safety while driving at night. The system uses an ultrasonic sensor to detect obstacles, a MEMS sensor to detect falls (to indicate whether the robot has fallen or is upright) and a vibration sensor to detect collisions. The Raspberry Pi drives a camera for image processing to detect an animal on the road. If an animal is present, an alarm sound is produced through a mini speaker to alert the driver. Alert SMS messages are also sent via a GSM module in case of abnormal sensor measurements or a collision. The robot can also be remotely controlled in four directions—forward, backward, left and right—via Bluetooth. Power is supplied by a 12 V battery. This prototype aims to use several sensors and communication modules to develop an assistive device that prevents accidents while driving in the dark.

Index Terms: Assistive Navigation System, Object Detection, Raspberry Pi, Ultrasonic Sensing, Real-Time Feedback

I. Introduction

This work proposes an intelligent system for vehicle safety using accident detection and notifications, implemented on a Raspberry Pi platform. It uses ultrasonic, MEMS and vibration sensors for collision and accident detection, and a camera to detect obstacles, all in real time. In the event of an accident, warnings are triggered by a speaker, while GSM alerts are also dispatched to contact persons for immediate action. It can also be manually operated via Bluetooth and is powered by a 12 V battery. Through real-time data monitoring, automatic accident warnings and obstacle detection, this system offers a reliable approach to prevent accidents and enhance driving safety [1].

This research proposes a cost-effective real-time vehicle accident monitoring system using Raspberry Pi and machine learning. The system uses sensors to monitor vehicle behaviour and enables instantaneous detection of collisions or anomalous events. Obstacle and hazard detection is achieved with a camera and machine learning. In the event of an accident, the system generates alarms and sends out notifications through the Global System for Mobile Communications (GSM), ensuring timely help and improved safety [2].

This paper describes a drowsiness detection and vehicle control system to ensure safe driving with the use of Raspberry Pi and Arduino. The proposed system tracks the driver's alertness level through eye-motion tracking and sensor monitoring to identify drowsiness. Real-time responses to detected drowsiness include vehicle speed adjustment or triggering alarms to promote safe operation. The combination of real-time tracking and vehicle interventions is shown to be effective in accident prevention and improving driving conditions [3].

This paper offers a real-time accident detection and reporting system using Raspberry Pi and IoT. It includes the use of sensors to monitor vehicle conditions and detect accidents or other anomalies. In the case of an accident, it provides immediate notifications and GPS coordinates through IoT communication to emergency services or contacts. This approach, which integrates real-time monitoring with automatic reporting, seeks to shorten response times, provide better emergency response and improve road safety [4].

This paper describes a new method of detecting and reporting accidents using Raspberry Pi with cloud computing. Real-time monitoring of the vehicle is carried out via sensors to detect accidents and other irregular events. Collision or abnormal events are automatically sent to the cloud for immediate reporting to pre-registered contacts and authorities. Using cloud-based monitoring and real-time data gathering, the system seeks to optimise accident response, road safety and emergency response times [5].

II. Related Works

This paper introduces a Convolutional Neural Network (CNN)-powered vehicle accident detection and warning system aimed at improving safety. It uses a CNN to process live sensor and video input data and detect accidents. When a crash is detected, it automatically raises an alarm and notifies designated family members. The integration of deep learning and real-time processing offers an efficient and accurate accident identification system for timely response [6].

This paper introduces a new smart vehicle security system combining driver's license verification and fingerprint recognition. The system guarantees vehicle security by automating double verification of the user's identity. The use of biometric and driver's license verification improves

vehicle security and avoids misuse. This method offers a strong, secure and automatic vehicle security system [7].

This paper presents an automatic messaging system for vehicle applications for accident detection. The system leverages sensors to track the vehicle's state and detect accidents or unusual circumstances. When an accident occurs, it automatically notifies the designated contacts in real time, along with the coordinates, to facilitate a quick response. The combination of real-time accident recognition and a real-time communication system is advantageous for addressing accidents and improving road safety [8].

This paper proposes an in-depth method for vehicle accident detection and remote alarm. It uses sensors to track vehicle status and performs real-time accident recognition and detection. When an accident or disturbance is detected, a remote alarm activates and relevant parties are notified of the incident and its location. This integrated approach of real-time accident detection and remote alarm notification seeks to reduce response time, increase safety and aid those affected [9].

This study reviews deep learning methods applied to autonomous vehicles, focusing on their use in facilitating intelligent decision making and safe vehicle operation. Major techniques, including convolutional neural networks, recurrent neural networks and reinforcement learning, are examined for various tasks such as object recognition, lane keeping and traffic forecasting. The research highlights the contribution of deep learning in enhancing vehicle autonomy, awareness and safety on roads. Through an examination of existing approaches and problems, the paper provides valuable insights into the design of safe and effective autonomous driving systems [10].

III. Proposed Method

The proposed system is a Raspberry Pi-powered prototype of a night-time highway collision alert system, implemented to provide drivers with greater safety during their journey by identifying obstacles and sending real-time warnings to the user. It incorporates an ultrasonic sensor to measure distances and detect obstacles, a MEMS sensor to detect fall conditions, and a vibration sensor to sense collisions. A camera module takes real-time pictures of the road, which are processed in order to detect any animals on the road, prompting a mini speaker to play a warning sound when required. A GSM module is also included in the system, through which predefined contacts receive SMS messages when deviations in sensor measurements or an accident occur, enabling appropriate responses. The robot can be manually operated forward, backward, to the right and to the left through Bluetooth, and it is run by a 12 V battery. By combining several sensors, image processing and communication modules, the system offers comprehensive safety assistance that minimizes accidents while travelling on the highway at night.

A. Block Diagram

The block diagram of the proposed Raspberry Pi-based night-time highway collision alert system is shown in Figure 1. The Raspberry Pi acts as the central processing unit that interfaces with the sensors, the camera and the communication modules described in the following sections.

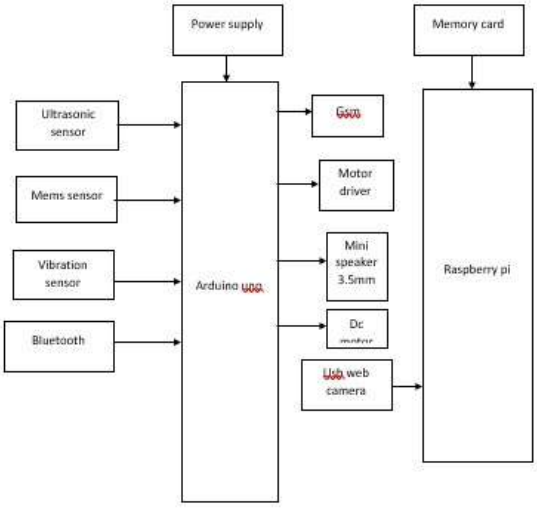

Figure 1: Block diagram of the proposed night-time highway collision alert system

B. Principle of Functioning

The proposed night-time highway collision alert system is developed to make roads safer by identifying obstacles on the road, especially animals, and alerting drivers in real time. The system pays constant attention to its environment by employing a set of sensors and a camera module. The processing unit is a Raspberry Pi, which processes the acquired data and performs sensor fusion to make decisions.

The camera module captures live video of the roadway, which is processed by the Raspberry Pi to recognize animals and any other possible impediments. The ultrasonic sensor measures the distance to objects in the path, providing additional situational awareness. Fall conditions are detected by a MEMS sensor, although it does not identify the direction in which the robotic unit or sensor platform has tipped over. The vibration sensor detects collisions and produces instant messages regarding life-threatening situations.

When an obstacle has been identified, a mini speaker emits an audio signal to alert other drivers around. At the same time, abnormal sensor readings or collisions are sent out via the GSM module as SMS alerts by the system. The combination of local and remote alerts ensures timely communication of hazards.

C. Hardware and Alerts

The hardware of the proposed system includes a Raspberry Pi, camera, ultrasonic sensor, MEMS sensor, vibration sensor, mini speaker, GSM module and Bluetooth interface. The main control node is the Raspberry Pi, which processes

images, detects objects, collects sensor data and connects all the parts together. A camera module is used to take real-time pictures to identify animals or objects on the road, with the ultrasonic sensor measuring the distance between the vehicle and objects, which helps in avoiding collisions. The MEMS sensor detects fall conditions to alert the drivers in case the system is tilted over, and the vibration sensor senses collisions and raises immediate alerts. Audible warnings through the mini speaker ensure that drivers in the surroundings are made aware of potential hazards. In addition, the GSM module reports information about critical events through SMS notifications to predefined contacts, and Bluetooth-based communication enables manual control of the robot in the forward, backward, left and right directions.

D. Power Requirements

The system has a 12 V battery that supplies constant and consistent power to the Raspberry Pi, sensors, camera, GSM module and speaker. Effective power management provides continuous condition monitoring, dependable obstacle recognition and timely warnings. This design facilitates portability and ensures effectiveness and efficiency, and thus the system can be applied to real-time night-time highway safety.

E. Performance Comparison

Table 1 summarizes the components of the proposed system and their functions. The suggested night-time collision alert system increases highway safety by incorporating a Raspberry Pi, camera, ultrasonic sensor, MEMS sensor, vibration sensor, mini speaker, GSM communication module and Bluetooth interface. The camera and real-time detection algorithms recognize animals and obstacles, while the ultrasonic and MEMS sensors observe the distance and fall conditions. Speaker, vibration and SMS alerts are provided in order to warn drivers and notify predefined contacts. Manual control is activated through Bluetooth, and a 12 V battery allows the system to operate in a stable and portable manner, which is why it can be effectively applied to night-time safety in real time.

TABLE 1: COMPONENTS AND SPECIFICATIONS OF THE PROPOSED SYSTEM

Parameter	Specification / Metric	Description
Central Controller	Raspberry Pi	Acts as the main processing unit, managing image processing, object detection, sensor data acquisition, and coordination of all system components.
Image Acquisition	Camera Module	Captures real-time video of the road to detect animals and obstacles during night-time driving.
Object Detection	Real-Time Detection Algorithms	Processes captured images to accurately identify animals and other obstacles in the path.
Collision Detection	Vibration Sensor	Detects collisions or impacts, triggering immediate alerts to enhance safety.
Obstacle Distance Measurement	Ultrasonic Sensor	Measures distance to nearby obstacles, supporting collision avoidance and timely warnings.
Fall Detection	MEMS Sensor	Identifies fall or tilt conditions of the robotic unit or sensor platform, alerting drivers if tipped over.
Audio Alerts	Mini Speaker	Generates audible warnings to inform nearby drivers of potential hazards.
Emergency Communication	GSM Module	Sends SMS notifications with critical event details to predefined contacts during emergencies.
Manual Control	Bluetooth Interface	Enables manual movement of the robot in forward, backward, left, and right directions.
Power Supply	12 V Battery	Provides stable and portable power to all system components for continuous operation.

Table 2 presents a comparative analysis of conventional techniques and the proposed approach. The proposed night-time collision alert system enhances traditional highway safety approaches because it enables real-time recognition of objects and animals with the help of a Raspberry Pi and camera. It incorporates a collision sensor (vibration), a distance sensor (ultrasonic) and a fall detector (MEMS). Emergency communication (GSM) and live location (GPS) are also supported by the system, and it can be controlled manually via Bluetooth. This system is a comprehensive solution to night-time highway safety as opposed to traditional approaches, which lack real-time monitoring, precise feedback, all-round obstacle detection and improved situational awareness.

TABLE 2: COMPARATIVE ANALYSIS OF CONVENTIONAL TECHNIQUES AND THE PROPOSED APPROACH

Parameter	Existing Methods	Proposed Approach (Our System)
Object Detection	Limited or no real-time detection; relies on driver alertness or basic sensors.	Real-time animal and obstacle detection using Raspberry Pi and camera for continuous monitoring of the road.
Collision Detection	No dedicated collision monitoring; relies on driver response.	Vibration sensor detects collisions and triggers immediate alerts for safety.
Distance Measurement	No accurate distance measurement; drivers rely on visual estimation.	Ultrasonic sensor provides real-time distance measurement to nearby obstacles for collision avoidance.
Processing Unit	Basic or non-intelligent systems with limited processing capability.	Raspberry Pi manages image processing, sensor integration, and overall system control.
Emergency Communication	No automatic alert system for accidents or hazards.	GSM module sends SMS alerts with critical event information to predefined contacts.

Parameter	Existing Methods	Proposed Approach (Our System)
Fall/Tilt Detection	Not available in conventional systems.	MEMS sensor detects fall or tilt conditions of the system to warn users.
Manual Control	Not supported; fully dependent on driver.	Bluetooth interface enables manual control of the robot in forward, backward, left, and right directions.
Location Tracking	Not available; no geolocation support.	GPS module provides live location data shared with emergency alerts.

IV. Results

A. Prototype Setup of the IoT-Based Embedded Monitoring and Control System

Figure 2 depicts the hardware prototype, which consists of several embedded and IoT components used for real-time monitoring and control applications. The system is based on a Raspberry Pi and an Arduino microcontroller that organize the data collection and processing duties. A GSM module enables remote communication, allowing the system to transmit alerts or sensor data over cellular networks. Jumper wires are used to connect the various sensors and interface modules, making it easy to measure environmental and system parameters. Power control is achieved using a battery and regulated supply units that give a steady power flow to all the parts. The layout illustrates a compact and modular system suitable for automation, remote monitoring and smart-system applications.

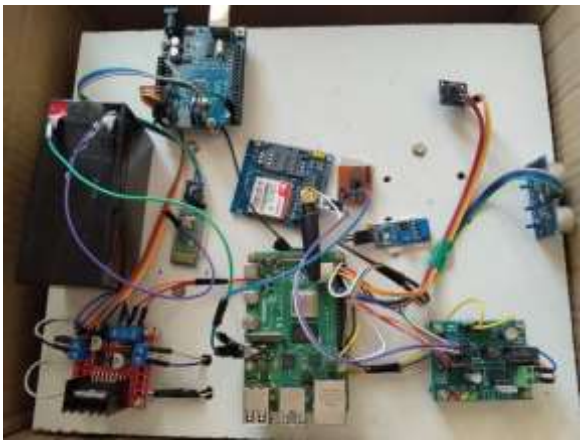

Figure 2: Prototype setup of the IoT-based embedded monitoring and control system

B. Experimental Setup of the Smart Surveillance and Sensor-Based Embedded System

Figure 3 shows the prototype of the smart surveillance and sensor-based embedded system developed for monitoring and automation. It is designed around a Raspberry Pi, which acts as the central unit processing sensor information and image input. It includes a USB camera module and an ultrasonic sensor, which are used to capture real-time images and to detect distances and objects, respectively. Jumper wires connect the additional interface modules and control circuits and provide communication between components. A GSM module enables remote alerts and data transmission. The system is powered by an external battery and regulated supply circuits to maintain stable operation. The overall structure reflects a compact and flexible design, which can be used in security, automation and IoT-based projects.

Figure 3: Experimental setup of the smart surveillance and sensor-based embedded system

V. Conclusion

This paper introduces a Raspberry Pi-powered night-time crash alert system that improves the safety of highway users. The system offers all-inclusive situational awareness capabilities by incorporating a camera to detect obstacles in real time, ultrasonic and MEMS sensors to detect distance and falls, and a vibration sensor to detect collisions. The alerts are realized by using audio warnings and GSM-based notifications to predefined contacts, allowing them to obtain help in a timely manner in case of an emergency. Portability and usability are enhanced by manual control over Bluetooth and a 12 V battery set-up. The proposed prototype proves the efficiency of integrating several sensors and real-time surveillance to minimize accidents, enhance the responsiveness of drivers and promote overall safety on the road at night.

References

1. Kumar, M. A. K. Akhtar, A. Pandey and R. P. Srivastava, “Smart City Vehicle Accident Monitoring and Detection System Using MEMS, GSM, GPS and Raspberry Pi 4,” IETE Journal of Research, vol. 69, no. 11, pp. 8121–8129, 2022.
2. R. Choppelli and P. Gupta, “Smart Driver Safety Alert System Using Raspberry Pi for Real-Time Road Hazard Detection,” International Journal of Engineering Research and Science & Technology, vol. 12, no. 1, pp. 10–19, 2016.
3. H. S. Badhan and S. K. Oza, “Accident Detection Using Raspberry Pi,” International Journal for Research in Applied Science and Engineering Technology, vol. 11, no. VI, Jun. 2023.
4. M. Parvathi Devi and N. Markandeya Gupta, “Design and Development of Vehicular Monitoring, Tracking and Accident Identification System Using Raspberry Pi,” International Journal of Engineering Research & Technology (IJERT), vol. 5, no. 11, Nov. 2016.
5. R. D. Tiwari and P. P. Tasgaonkar, “IoT Based Vehicle Accident Prevention and Detection System Using

Raspberry-Pi," International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), vol. 10, no. 10, pp. 19–29, Jul.–Aug. 2023.

6. Mhetre, Y. Jadhav, T. Karangutkar and R. Wakchaure, "Smart Accident Detection and Alert System Using Raspberry Pi," International Journal for Research in Applied Science & Engineering Technology (IJRASET), 2025.
7. Anjana G, A. C. Sureshkumar, Athira H, Harsha S and Ambarish A, "Enhancing Driver Safety: Deep Learning Approach for Drowsiness Detection and Accident Prevention," Journal of IoT in Social, Mobile, Analytics, and Cloud, vol. 6, no. 2, pp. 84–97, 2024.
8. R. Krishna Peddarapu, B. Likhita, D. Monika and S. Preeti Paruchuru, "Raspberry Pi-Based Driver Drowsiness Detection," in Proc. 2024 IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT), 2024.
9. Athul Krishna EM, G. S. Kumar, S. Kumar P, H. K. P and L. C. Manikandan, "Drowsiness Detection System for Vehicles Using Raspberry Pi," International Journal for Research in Applied Science & Engineering Technology (IJRASET), 2025.
10. M. E. Sahin, "Real-Time Driver Drowsiness Detection and Classification on Embedded Systems Using Machine Learning Algorithms," Technical Sciences (IIETA), pp. 847–856, 2023.