

Intelligent Accident Prevention and Alert System Using Sensors and Machine Learning

Kavitha K.¹, Jayanth Arivazhagan²

¹Assistant Professor, ²UG Student, Department of Electronics and Communication Engineering, Panimalar Engineering College, Chennai, India.

E-mail: ¹Kavithak@panimalar.ac.in, ²apjayanth2002@gmail.com

Abstract

Road accidents are one of the primary causes of death around the globe, and these can be avoided if timely actions are taken by the driver of the vehicle. This paper proposes a system known as the Intelligent Accident Prevention and Alert System, which makes use of various sensors and machine learning algorithms to predict potential hazards on the road in real time. This system utilizes data from various sensors such as accelerometers, gyroscopes, GPS, proximity sensors, and driver sensors. This data is fed into a feature extraction module, where a random forest algorithm is utilized to classify the level of risk of an accident occurring. Based on this, an alert signal is sent to the driver, enabling them to take timely action. A feedback mechanism has been included in the system to ensure dynamic risk assessment. The performance of the proposed system is evaluated through a scenario-based simulated dataset, and the results show an accuracy of 93.5%, thereby proving the efficiency and reliability of the proposed system in detecting hazardous driving conditions. The proposed system also provides timely alerts, thereby enhancing the efficiency and effectiveness of accident prevention. The results prove that the proposed system offers an efficient and effective solution for accident prevention in real-world applications.

Keywords: Intelligent Accident Prevention System, Machine Learning, Sensor Fusion, Risk Prediction, Driver Alert System, Intelligent Transportation Systems.

1. Introduction

Road accidents are one of the prominent issues in today's global scenario, resulting in substantial loss of life and property. According to recent reports, a considerable percentage of accidents is attributed to human factors, including delayed response time, lack of situational awareness, and improper decision-making during critical situations. Conventional safety measures are mostly concerned with post-accident detection and reporting, which is not adequate to prevent accidents from occurring in the first place. Hence, there is an urgent need to introduce intelligent systems to detect critical situations and assist drivers in taking corrective actions in a timely manner.

With the development of Internet of Things (IoT) technology and artificial intelligence, modern vehicle safety systems have evolved to monitor and analyze data in real time. Sensor-based solutions, such as accelerometers, gyroscopes, GPS, and proximity sensors, help collect data from various parameters of a vehicle in real time. However, such solutions based on individual sensors or rule-based thresholds have shown lower accuracy and high false alarm rates. To improve these limitations, machine learning is being used to analyze various parameters of a vehicle and enhance the accuracy of risk prediction.

The current paper proposes an "Intelligent Accident Prevention and Alert System" that combines data fusion and machine learning-based risk assessment to forecast possible accident situations. The system utilizes a Random Forest classification algorithm to process the extracted features from the sensor data and calculate the level of risk associated with the driving conditions. According to the predicted level of risk, the system provides multilevel alerts to the driver to help him react quickly to critical situations. Moreover, emergency notification and vehicle-to-vehicle communication are also implemented to improve road safety.

The proposed system employs a proactive approach by continuously monitoring driving conditions and adapting risk predictions through a feedback loop. This helps the system cope with changing driving conditions and enhance its decision-making ability. The performance of the system is tested through experimental analysis based on various scenarios. This helps to improve the accuracy of hazards detected by the system and minimize the reaction time of the driver.

2. Related Work

Due to the recent developments in intelligent transportation systems, numerous accident detection and prevention frameworks have been proposed based on the Internet of Things, machine learning, and sensor fusion techniques. Various studies have been conducted to improve road safety by providing real-time monitoring and alert mechanisms. In this paper, we propose a smart accident detection and alert system based on IoT and sensor fusion techniques.

A machine learning-based framework was developed by Hozhabr Pour et al. [1] for the automatic detection of accidents based on multimodal sensor integration within a vehicle. This approach was found to increase the accuracy of detecting accidents by utilizing multiple sources of data. Nevertheless, the main idea of this system was to increase accuracy in post-accident situations. Jayanthi et al. [2] developed an IoT-based system utilizing a sensor network and a KNN algorithm for the early detection of road injuries. This system helps in the timely detection of injuries, but a simple classification technique may not provide an accurate prediction.

There are various studies that propose solutions for accident detection and emergency notification using mobile and IoT technologies. Vasireddy and Sagar proposed a real-time accident detection system for mobile devices that sends emergency notifications using sensors [3]. Furthermore, Alsayydeh et al. proposed a complete accident detection and alert system using vehicle sensors and communication systems [4]. These systems are efficient in reducing response time in the event of an accident; however, there is no advanced predictive feature for preventing accidents.

Recent studies have also focused on the importance of artificial intelligence and sensor fusion for achieving better accuracy in detecting accidents. In a recent study, Reddy et al. [5] stressed the importance of sensor fusion along with artificial intelligence for achieving better accuracy in accident detection and classification in smart cities. In another study, Balfaqih et al. [6] proposed a system based on IoT and machine learning for accident detection, achieving better performance in terms of classification accuracy. Tasgaonkar et al. [7] suggested an IoT framework for smart city applications, primarily focusing on accident detection and reporting. However, the studies mainly focus on accident detection rather than risk prediction.

Deep learning techniques are also being explored to improve the performance of the system. Pathik et al. suggested an IoT and deep learning-based accident detection system using AI, and the results indicate higher accuracy in identifying accident scenarios. Uma and Eswari proposed an IoT and machine learning-based accident prevention and safety assistance system, which attempts to predict accident scenarios but lacks detailed feedback mechanisms. Bhakat et al. suggested a vehicle accident detection and alert system using IoT and artificial intelligence, which mainly focuses on sending notifications but lacks emphasis on various levels of driver feedback.

It is clear from the literature that most studies are focused on accident detection and sending notifications, while there is limited focus on risk prediction and driver assistance. Moreover, most studies are based on single sensor data, whereas there is limited use of continuous monitoring systems, making them less reliable in dynamic driving scenarios.

To overcome the aforementioned limitations, the proposed system utilizes the multi-sensor data fusion technique along with machine learning for risk prediction thereby preventing accidents proactively. Unlike the previously proposed systems, the proposed system includes a continuous monitoring technique along with multi-level alert systems and feedback for effective accident prevention.

3. Research Gap

Despite improvements in accident detection and alert technology, limitations exist. Current technology primarily focuses on post-accident detection instead of prevention. This technology mostly relies on threshold-based approaches. Machine learning methods have been developed to improve accuracy; however, some approaches are limited to offline use or specific tasks. There is a lack of comprehensive prevention frameworks. IoT technology improves communication but relies on predetermined rules, which restricts its ability to adapt to changing conditions. There is a lack of multi-sensor fusion approaches and real-time machine learning. There has been insufficient exploration of low-latency edge-based approaches. Current technology does not provide a feedback mechanism reducing its effectiveness in critical situations since it does not provide varying feedback.

In addition, existing methods mostly use simulated data, which might not be representative of actual scenarios, leading to overestimated performance in certain cases.

Furthermore, issues such as sensor noise, data inconsistency, and data synchronization in a multi-sensor system are often not considered in existing methods. Binary classification of risk is also a limiting factor in representing actual scenarios, and the contribution of driver physiological data is often not clearly validated.

4. Methodology

The proposed system consists of a multi-stage framework. The system includes data acquisition through sensors, prediction through machine learning, and alert generation. The overall structure of the system is depicted in Figure 1, shows the interaction between the modules.

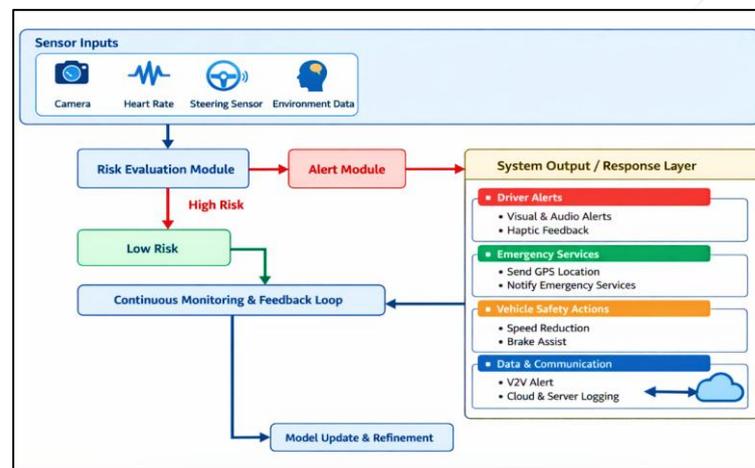


Figure 1. Block Diagram of the Proposed Work

The system also collects real-time data from multiple sensors, such as cameras, heart rate sensors, steering sensors, and environmental sensors. The data collected by the system are then preprocessed to remove inconsistencies and noise. The preprocessed data are then processed to extract significant parameters, such as acceleration, steering, deceleration rates, and environmental changes. The extracted parameters are then input to the Random Forest-based machine learning model. The input data are analyzed by the Random Forest model to generate a risk score indicating the possibility of an accident. The system then classifies the driving conditions as low or high risk based on the generated risk score and a predetermined threshold. In high-risk conditions, the system activates the alert module to provide multiple levels of warnings to the driver to take immediate action. The system sends emergency

messages with GPS coordinates to the relevant authorities. In addition, the system also reduces the speed and provides brake assistance to improve vehicle safety.

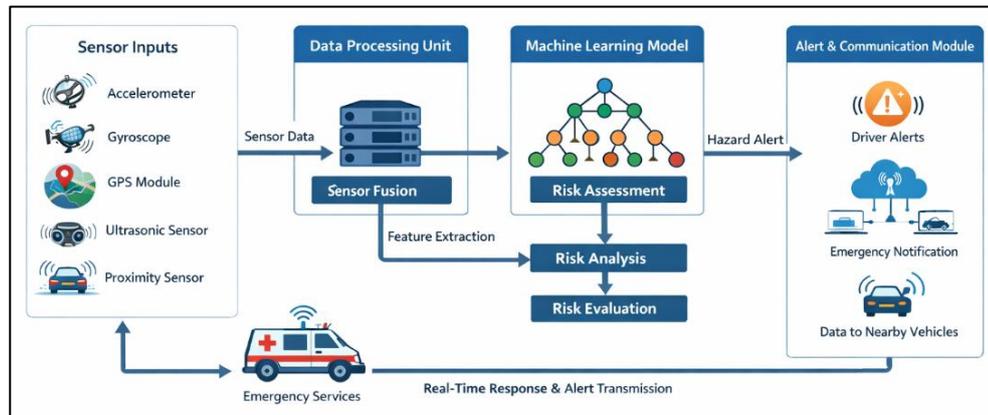


Figure 2. System Architecture

The system also allows for vehicle-to-vehicle communication and cloud-based data logging for a better understanding of the situation. Conversely, during low-risk situations, the system enables continued real-time monitoring without any alarms, ensuring efficient operation with minimal false alarms. A feedback loop has been incorporated into the system to ensure that the sensors are updated and the risk is recalculated for a more adaptive system in varying driving conditions. The machine learning algorithm is also updated using newly collected data for more precise predictions and efficient system operation. Figure 2 illustrates the architecture of the proposed system.

5. Results and Discussion

5.1 Simulation Setup

The performance of the proposed work is evaluated through a simulation environment that mimics actual driving conditions. The simulation environment is implemented using a Python framework, where machine learning algorithms are used to train and evaluate the model. The system takes multi-sensor data inputs, which include accelerometer, gyroscope, GPS, and driver physiological signals. The experiment is conducted on a system with standard computational resources. In this case, the Random Forest classifier is employed to conduct risk prediction. In addition, the simulation environment has the ability to simulate normal and hazardous conditions. This means that the system can be evaluated under different conditions.

The dataset employed in the evaluation of the model has 5,000 instances. This dataset is generated based on simulated driving scenarios. In this case, normal driving, hard braking, sharp turn, and proximity to an object are considered. To obtain unbiased results, the dataset is split into training and testing sets. Each instance in the dataset has multi-sensor features, including acceleration, steering behavior, speed variation, and proximity to an object. The dataset contains two classes. One class represents low-risk conditions, whereas the other class represents hazardous conditions.

The performance of the proposed system is evaluated and determined using several performance measures, including accuracy, precision, recall, F1 score, specificity, and false positive rate. All these metrics are derived from the confusion matrix.

Accuracy

$$\begin{aligned} \text{Accuracy} &= \frac{TP + TN}{TP + TN + FP + FN} \\ &= \frac{93 + 94}{200} = 93.5\% \end{aligned}$$

Accuracy is a measure of the correctness of the model by checking the percentage of correctly classified instances out of the total predictions made by the model. The proposed system has an accuracy of 93.5%, making it a reliable system.

Precision

$$\begin{aligned} \text{Precision} &= \frac{TP}{TP + FP} \\ &= \frac{93}{93 + 6} = 93.9\% \end{aligned}$$

Precision is a measure of the percentage of correctly predicted hazardous instances out of the total predicted hazard instances by the model. The proposed system has a precision of 93.9%, making it a system with fewer false alarms.

Recall

$$\begin{aligned}\text{Recall} &= \frac{TP}{TP + FN} \\ &= \frac{93}{93 + 7} = 93.0\%\end{aligned}$$

Recall is a measure of the ability of the system to correctly predict the actual hazardous condition. The proposed system has a recall of 93.0%, making it an effective system for hazard detection.

F1score

$$\begin{aligned}\text{F1} &= 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \\ &= 93.4\%\end{aligned}$$

The F1-Score is a combination of precision and recall that indicates the effectiveness of the system. The proposed system has an F1-Score of 93.4%.

Specificity

$$\begin{aligned}\text{Specificity} &= \frac{TN}{TN + FP} \\ &= \frac{94}{94 + 6} = 94.0\%\end{aligned}$$

Specificity evaluates the model's ability to correctly identify normal driving conditions. The system achieves a specificity of 94.0%, minimizing incorrect hazard detection.

False Positive Rate

$$\begin{aligned}\text{FPR} &= \frac{FP}{FP + TN} \\ &= \frac{6}{100} = 6.0\%\end{aligned}$$

The percentage of typical circumstances that are deemed dangerous is known as the False Positive Rate. The FPR of the suggested system is a low 6.0%.

Latency Analysis

The latency of the system, or the amount of time it takes to generate the alerts, determines how well the suggested system performs in a real-time setting. The suggested system has a maximum latency of 120 ms and an average latency of about 95 ms.

5.3 Driver Alert System Evaluation

The performance of the alert system can be measured in terms of its capability to support the driver's response in critical situations. As depicted in Figure 3, the alert system provides real-time visual alerts to the driver, offering information about critical situations, along with relevant details like the risk score and obstacles detected.

The multi-level alert system provides visual, audio, and haptic feedback to the driver, ensuring that the driver receives timely information. The implementation of the alert system leads to a significant improvement in the driver's response time, reducing it from 1.5-2.0 sec to 0.8-1.2 sec, which shows an improvement of almost 40-50%.

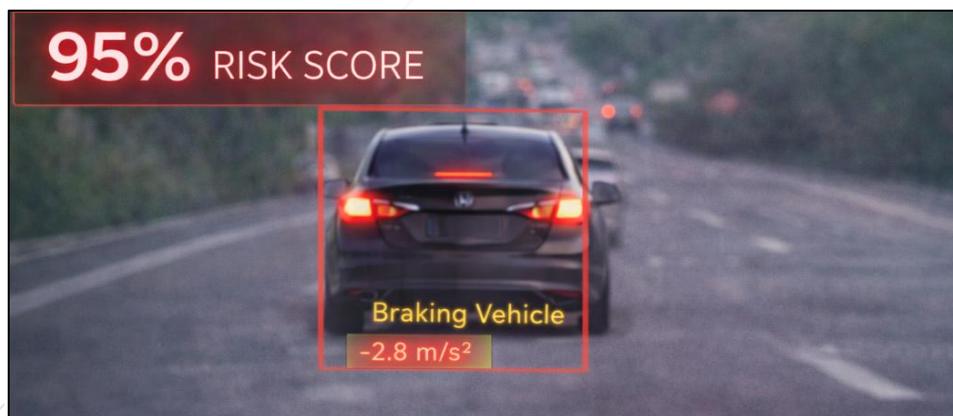


Figure 3. Visual Alert Interface

Figure 3 shows a real-time visual alert generated by the proposed system, where a high-risk condition is identified with a risk score of 95%. The system detects a braking vehicle ahead and provides immediate visual feedback to help the driver take corrective action in a timely manner.

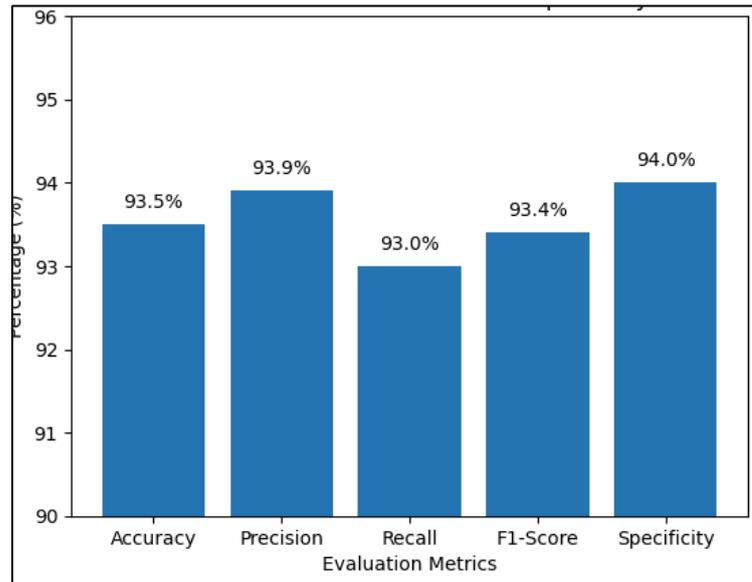


Figure 4. Performance Evaluation Metrics of the Proposed System

Figure 4 shows a bar diagram representing the performance evaluation metrics of the proposed system, where all metrics are found to be above 93%.

Discussion

The experimental results proved that the proposed work successfully overcame the limitations of existing accident detection systems by providing risk prediction and generating alerts in real-time. Moreover, the use of multi-sensor data helps improve the robustness of the system, while the use of a Random Forest algorithm helps classify the driving conditions accurately.

The false positive rate is low, which reduces the false alarm rate, thereby enhancing user acceptance of the system. In addition, the continuous monitoring and feedback contribute to the improvement of the system's adaptability in a dynamic environment. However, the system was implemented in a simulated environment. There are a few challenges consider when it is implemented in a real-world environment. The proposed system has shown promising results, but it was implemented in a simulated environment, which may not accurately reflect the actual environment. The actual environment may be affected by sensor noise, latency, and inconsistencies, which may impact system performance. In addition, the binary classifier may not accurately reflect the actual risks, and it should be validated to make the proposed system reliable.

6. Conclusion

The proposed work utilizes multi-sensor data fusion and machine learning-based risk prediction to ensure real-time road safety. The system employs multi-sensor data fusion and a Random Forest model to analyze driving behavior and provide accident prevention and alert capabilities. Moreover, the experimental results show that the proposed system achieves an accuracy of 93.5%, demonstrating its reliability for ensuring real-time road safety. Furthermore, the proposed Intelligent Accident Prevention and Alert System offers real-time multi-level alert systems to enable quicker responses to potential accidents. However, the study has some limitations, as it relies on simulated data and does not consider real-world driving conditions for the validation of the proposed system.

References

- [1].Hozhabr Pour, Hawzhin, Frédéric Li, Lukas Wegmeth, Christian Trense, Rafał Doniec, Marcin Grzegorzek, and Roland Wismüller. "A machine learning framework for automated accident detection based on multimodal sensors in cars." *Sensors* 22, no. 10 (2022): 3634.
- [2].Jayanthi, L. N., R. Usha, G. Sekar, V. T. Lakshmi, and N. Mohankumar. "Early Detection of Road Traffic Injuries with IoT Sensor Networks and K-Nearest Neighbors Algorithm." In *2025 International Conference on Visual Analytics and Data Visualization (ICVADV)*, pp. 773-778. IEEE, 2025.
- [3].Vasireddy Satish, and Pyla Karuna Sagar. "Real-time Accident Detection and Emergency Notification System for Mobile Devices." *ijraset Journal For Research in Applied Science and Engineering Technology*. 2025. <https://doi.org/10.22214/ijraset.2025.73438>
- [4].Alsayaydeh, Jamil Abedalrahim Jamil, Mohd Faizal bin Yusof, Mohamad Amirul Aliff Abdillah, Ahmed Jamal Abdullah bin Al-Gburi, Safarudin Gazali Herawan, and Andrii Oliinyk. "Enhancing Vehicle Safety: A Comprehensive Accident Detection and Alert System." *International Journal of Advanced Computer Science & Applications* 14, no. 11 (2023).

- [5].Reddy, K. Ramakrishna, T. Sathish Kumar, Sreenivasulu Gogula, Abhisek Sethy, Veeraswamy Ammisetty, M. N. Sharath, Koppuravuri Gurnadha Gupta, Ravi Kiran, and Lavish Kansal. "Harnessing sensor fusion and AI for accurate accident detection and classification in the safety of smart cities." In MATEC Web of Conferences, vol. 392, p. 01102. EDP Sciences, 2024.
- [6].Balfaqih, Mohammed, Soltan Abed Alharbi, Moutaz Alzain, Faisal Alqurashi, and Saif Almilad. "An accident detection and classification system using internet of things and machine learning towards smart city." Sustainability 14, no. 1 (2021): 210.
- [7].Tasgaonkar, Pankaj P., Rahul Dev Garg, and Pradeep Kumar Garg. "An IoT-based framework of vehicle accident detection for Smart City." IETE Journal of Research 70, no. 5 (2024): 4744-4757.
- [8]. Pathik, Nikhlesh, Rajeev Kumar Gupta, Yatendra Sahu, Ashutosh Sharma, Mehedi Masud, and Mohammed Baz. "AI enabled accident detection and alert system using IoT and deep learning for smart cities." Sustainability 14, no. 13 (2022): 7701.
- [9]. Uma, S., and Rajagopal Eswari. "Accident prevention and safety assistance using IOT and machine learning." Journal of Reliable Intelligent Environments 8, no. 2 (2022): 79-103.
- [10]. Bhakat, Akash, Neetigya Chahar, and V. Vijayasherly. "Vehicle accident detection & alert system using IoT and artificial intelligence." In 2021 Asian conference on innovation in technology (ASIANCON), pp. 1-7. IEEE, 2021.