

AI-POWERED SMART TRAFFIC MANAGEMENT AND ACCIDENT ALERT SYSTEM USING COMPUTER VISION AND IOT

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Abstract: The rapid increase in vehicle population has led to significant challenges in traffic management and road safety. Conventional traffic systems rely on fixed signal timings and manual monitoring, which are inefficient under dynamic conditions. This paper presents an AI-Powered Smart Traffic Management and Accident Alert System using Computer Vision and IoT technologies. The system captures real-time traffic data through smart cameras and processes it using image processing and deep learning techniques to detect vehicles and estimate traffic density. Based on this analysis, traffic signals are dynamically controlled to optimize traffic flow and reduce congestion. In addition, the system incorporates an automatic accident detection mechanism that identifies abnormal events such as collisions or sudden stops. Upon detection, alerts are instantly sent to nearby hospitals and police stations along with location details. The system also notifies family members using a secure cloud-based database, ensuring timely communication during emergencies. The proposed solution integrates traffic control, accident detection, and emergency response into a unified platform, improving efficiency, reducing response time, and enhancing road safety. This system is scalable and suitable for smart city applications.

Keywords: Artificial Intelligence (AI), Computer Vision, Intelligent Traffic Management, Accident Detection, Internet of Things (IoT), Smart Cities, Deep Learning, YOLO, Real-Time Monitoring, Emergency Alert System

I. INTRODUCTION

The rapid growth of urbanization and the exponential increase in the number of vehicles have led to severe traffic congestion and road safety challenges

across the world. In many urban areas, traffic jams, delays, and accidents have become common occurrences, resulting in economic losses, environmental pollution, and loss of human lives. Traditional traffic management systems primarily rely on fixed signal timings and manual monitoring, which are not capable of adapting to real-time traffic variations. As a result, these systems often lead to inefficient utilization of road infrastructure and increased waiting times at intersections.

With the advancement of modern technologies, there is a growing need for intelligent and automated traffic management solutions that can dynamically respond to changing traffic conditions. Artificial Intelligence (AI), Computer Vision, and the Internet of Things (IoT) have emerged as key enabling technologies for developing smart transportation systems. These technologies allow real-time data acquisition, analysis, and decision-making, enabling traffic systems to operate more efficiently and autonomously.

Computer vision techniques play a crucial role in analyzing traffic scenes by processing video feeds from surveillance cameras. Using advanced image processing and deep learning models such as You Only Look Once (YOLO), vehicles can be detected, classified, and tracked in real-time. This enables accurate estimation of traffic density, identification of congestion patterns, and detection of abnormal events such as accidents or sudden vehicle stoppages. Compared to traditional sensor-based systems, vision-based approaches provide richer information and greater flexibility.

In addition to traffic congestion, road accidents remain a major concern, especially in densely populated areas. Delayed emergency response is one of the critical factors contributing to the severity of accidents. In most cases, accidents are reported manually, which leads to delays in notifying emergency services such as hospitals and police stations. Therefore, there is a strong need for automated accident detection and alert systems that can ensure timely response and potentially save lives.

To address these challenges, this paper proposes an AI-Powered Smart Traffic Management and Accident Alert System that integrates multiple functionalities into a single platform. The system uses real-time video input from cameras installed at road junctions and processes it using computer vision and machine learning algorithms. Based on the analysis of vehicle movement and traffic density, the system dynamically adjusts traffic signal timings and supports adaptive lane management to improve traffic flow and reduce congestion.

Furthermore, the proposed system incorporates an intelligent accident detection mechanism that identifies abnormal vehicle behavior, such as sudden deceleration, collisions, or irregular motion patterns. Once an accident is detected, the system automatically triggers alerts and sends location details to nearby hospitals and police stations through cloud-based communication platforms. Additionally, it notifies family members using a secure pre-registered database, ensuring rapid communication during emergencies.

Another important aspect of the proposed system is its scalability and adaptability for smart city applications. By leveraging cloud computing and IoT infrastructure, the system can be easily deployed across multiple locations and integrated with existing traffic management systems. The use of cloud platforms such as Firebase enables real-time data storage, processing, and communication, ensuring reliability and efficiency.

The main contribution of this work lies in the comprehensive integration of traffic monitoring, intelligent signal control, accident detection, and emergency alert mechanisms into a unified framework. Unlike existing approaches that address these components independently, the proposed system provides a holistic solution that enhances traffic efficiency and public safety simultaneously. The system reduces human intervention, improves decision-making accuracy, and ensures faster emergency response.

In summary, this research aims to develop a smart, efficient, and scalable traffic management system that leverages AI and IoT technologies to address real-world transportation challenges. The proposed solution not only improves traffic flow and reduces congestion but also plays a vital role in saving lives by enabling quick and automated emergency response. Therefore, it represents a significant step toward the development of intelligent transportation systems and smart cities.

II. RELATED WORK

In recent years, extensive research has been conducted in the field of intelligent transportation systems, focusing on traffic management, accident detection, and emergency response using Artificial Intelligence (AI), Computer Vision, and Internet of Things (IoT) technologies. These studies aim to improve traffic efficiency and enhance road safety; however, most existing solutions address these challenges in isolation rather than as an integrated system.

Zhang et al. (2020) proposed a real-time traffic flow detection system using deep learning and computer vision techniques. Their approach utilized convolutional neural networks (CNNs) to detect and classify vehicles from live video streams, achieving high accuracy in traffic density estimation. While the system demonstrated strong performance in vehicle detection, it was limited to traffic monitoring and did not incorporate dynamic signal control or accident detection mechanisms.

Sultana and Islam (2019) developed an IoT-based smart traffic management system that uses sensors and cloud platforms to monitor traffic conditions. Their model dynamically adjusts traffic signals based on sensor data, thereby reducing congestion. However, sensor-based systems often lack detailed visual insights and are less effective in complex urban environments compared to camera-based solutions using computer vision.

Chen et al. (2021) introduced a deep learning-based accident detection system that identifies abnormal vehicle behavior such as sudden stops and collisions. The system also included an alert mechanism to notify emergency services. Although effective in accident detection, the model operates independently and does not integrate with traffic management systems, limiting its overall impact on traffic efficiency.

Patel and Shah (2018) proposed an image processing-based traffic control system that uses basic techniques such as background subtraction for vehicle detection. While the approach is computationally simple, it suffers from reduced accuracy under varying environmental conditions such as lighting changes and weather disturbances. Furthermore, the system does not include advanced AI models or accident detection features.

Kumar et al. (2022) presented an AI-based traffic management framework for smart cities that integrates traffic monitoring and emergency response

mechanisms. Their work highlights the importance of combining multiple functionalities. However, the system lacks real-time adaptive control using advanced deep learning techniques and does not fully address automated family notification or comprehensive alert systems.

Recent advancements in deep learning, particularly object detection models like YOLO (You Only Look Once), have significantly improved real-time vehicle detection accuracy and speed. These models are capable of processing video streams efficiently, making them suitable for real-time traffic applications. Similarly, cloud computing platforms such as Firebase have enabled seamless communication and data management, allowing instant transmission of alerts and real-time updates.

Despite these advancements, a major research gap still exists in the integration of traffic management, accident detection, and emergency response into a single unified system. Most existing approaches are either limited to monitoring traffic conditions or detecting accidents without providing a complete solution for real-time decision-making and communication.

To address these limitations, the proposed system combines computer vision-based traffic monitoring, AI-driven signal control, automatic accident detection, and cloud-based alert mechanisms into a single platform. By leveraging deep learning models such as YOLO and integrating IoT and cloud technologies, the system ensures accurate detection, real-time processing, and efficient communication. This holistic approach not only improves traffic flow but also enhances public safety by enabling faster emergency response and effective coordination among stakeholders.

III. PROPOSED SYSTEM AND METHODOLOGY

The proposed system is an integrated AI-based framework designed to perform real-time traffic monitoring, dynamic signal control, accident detection, and emergency alert generation. It leverages Computer Vision, Machine Learning, IoT, and cloud technologies to ensure efficient traffic management and enhanced road safety. The overall architecture of the system is illustrated in Fig. 1.

A. System Overview

The system operates by capturing live video streams from smart cameras installed at road intersections. These video feeds are processed using image processing and deep learning techniques to extract meaningful information such as vehicle count, traffic density, and motion patterns. Based on this analysis, the system dynamically adjusts traffic signals and detects abnormal events such as accidents.

The system is divided into four major modules:

Traffic Monitoring Module Traffic Control Module Accident Detection Module Alert and Communication Module

These modules work collaboratively to provide a unified and intelligent traffic management solution.

B. Traffic Monitoring Module

The traffic monitoring module is responsible for acquiring real-time video data from cameras. The captured frames are preprocessed using OpenCV techniques such as grayscale conversion, noise filtering, and background subtraction.

A deep learning-based object detection model, such as YOLO (You Only Look Once), is used to detect and classify vehicles in each frame. The model identifies different types of vehicles (cars, bikes, buses, etc.) and counts the number of vehicles present in each lane. This process is depicted in Fig. 1.

The output of this module is used to estimate traffic density and flow patterns, which are essential for decision-making in the control module.

C. Traffic Density Analysis and Control Module

The traffic density is calculated based on the number of vehicles detected within a specific time frame. The system classifies traffic conditions into categories such as low, medium, and high density.

Based on the calculated density, the system dynamically adjusts traffic signal timings. Lanes with higher traffic density are allocated longer green signal durations, while lanes with lower density receive shorter durations. This adaptive control mechanism ensures optimal utilization of road infrastructure and reduces congestion.

The communication process is designed to be real-time and reliable, ensuring minimal delay in alert delivery.

D. Cloud Integration and Data Management

The system utilizes cloud platforms for data storage, processing, and communication. Firebase is used to store user information, emergency contacts, and alert logs. This enables real-time synchronization and scalability of the system.

Cloud integration also allows remote monitoring and control, making the system suitable for large-scale smart city deployments.

E. Working Flow of the System

The overall workflow of the system can be summarized as follows:

Capture real-time video from cameras
Preprocess frames using image processing techniques
Detect and classify vehicles using deep learning models
Calculate traffic density and analyze flow patterns
Dynamically adjust traffic signals
Detect abnormal events (accidents)
Trigger alerts and send notifications via cloud
Notify emergency services and family members

IV. MATHEMATICAL MODEL

The proposed system uses mathematical formulations to estimate traffic density, allocate signal timing dynamically, and detect accident events based on motion analysis.

A. Traffic Density Estimation

Traffic density is calculated as the number of vehicles present in a particular lane within a given time interval. It is defined as:

The decision-making process is handled by a rule-based or AI-driven control algorithm, as shown in Fig. 2 (Flow

$$D_i = \frac{N_i}{T}$$

(1)

Diagram).

D. Accident Detection Module

The accident detection module identifies abnormal events by analyzing vehicle motion patterns. Sudden changes in speed, abrupt stops, collisions, or irregular trajectories are considered indicators of potential accidents.

The system uses motion analysis and deep learning techniques to detect such anomalies. For example, a sudden drop in velocity combined with irregular movement patterns may

where D_i represents the traffic density of lane i , N_i is the number of vehicles detected in lane i , and T is the observation time interval.

B. Normalized Traffic Density

To ensure uniform scaling of density values across different conditions, the density is normalized between 0 and 1 as follows:

$$D_i - D_{min}$$

indicate a collision. The detection process is continuously performed on incoming video frames.

$$D_{norm} =$$

$$\frac{D_i - D_{min}}{D_{max} - D_{min}}$$

(2)

Once an accident is detected, the system triggers an event flag and forwards the information to the alert module. This process is illustrated in Fig. 3 (Sequence Diagram).

E. Alert and Communication Module

The alert module is responsible for sending notifications to relevant authorities and stakeholders. Upon detecting an accident, the system extracts location information and sends alerts to nearby hospitals and police stations through a cloud-based communication platform such as Firebase.

In addition to emergency services, the system also notifies family members using a secure pre-registered database. This ensures timely communication and improves emergency re-sponse efficiency.

where D_{min} and D_{max} represent the minimum and maximum possible density values, respectively. This normalization helps in making consistent decisions for signal control.

C. Dynamic Signal Timing

Based on the normalized traffic density, the green signal duration is dynamically adjusted using the following equation:

$$G_i = G_{min} + (G_{max} - G_{min}) \times D_{norm} \quad (3) \text{ where } G_i \text{ is the green signal time allocated for lane } i, \text{ and}$$

Gmin and Gmax are the minimum and maximum allowable signal durations. This ensures that lanes with higher traffic density receive longer green signals.

D. Accident Detection Model

Accident detection is performed using motion analysis of vehicles. The system computes a score based on changes in velocity, acceleration, and trajectory deviation:

$$S = w_1\Delta v + w_2a + w_3\Delta p \quad (4)$$

where S is the accident detection score, Δv represents sudden change in velocity, a denotes acceleration, and Δp indicates deviation in vehicle trajectory. The parameters w_1 , w_2 , and w_3 are weight coefficients assigned to each factor.

If the computed score exceeds a predefined threshold, the event is classified as a potential accident, and the alert mechanism is triggered.

V. SYSTEM ARCHITECTURE

The system architecture of the proposed AI-Powered Smart Traffic Management and Accident Alert System is designed as a layered model consisting of five main components: Input Layer, Processing Layer, Control Layer, Output Layer, and Alert & Communication Layer. The overall architecture is illustrated in Fig. ??.

A. Input Layer

The input layer consists of multiple smart cameras installed at traffic junctions. These cameras continuously capture real-time video streams of traffic from different angles. The captured data serves as the primary input for further processing.

B. Processing Layer

The processing layer performs the core computation using computer vision and machine learning techniques. It includes the following steps:

- Video Acquisition: Captures frames from the live video stream
- Pre-processing: Applies image processing techniques such as noise reduction and frame enhancement using OpenCV
- Vehicle Detection: Uses deep learning models such as YOLO to detect and classify vehicles
- Traffic Density Estimation: Counts vehicles and analyzes congestion levels
- Accident Detection: Identifies abnormal events using motion analysis

This layer converts raw video data into meaningful information required for decision-making.

C. Control Layer

The control layer is responsible for intelligent decision-making. Based on the traffic density, traffic signal timings are dynamically adjusted and lane management is optimized to improve traffic flow. This ensures that high-density lanes receive longer green signals, thereby reducing congestion.

D. Output Layer

The output layer reflects the decisions made by the control system. Traffic signals at intersections are updated dynamically, leading to improved traffic flow and reduced waiting time.

E. Alert & Communication Layer

This layer handles emergency communication and data management. It includes accident alert generation, cloud-based data storage, and real-time notification mechanisms.

- Alerts are sent to nearby hospitals and police stations
- Family members are notified using a secure pre-registered database
- Cloud platforms such as Firebase are used for real-time communication and data storage

F. Overall Working

The system continuously captures traffic data, processes it using AI models, makes intelligent decisions for signal control, and responds to emergencies in real-time. All components are interconnected to provide a seamless and automated traffic management solution.

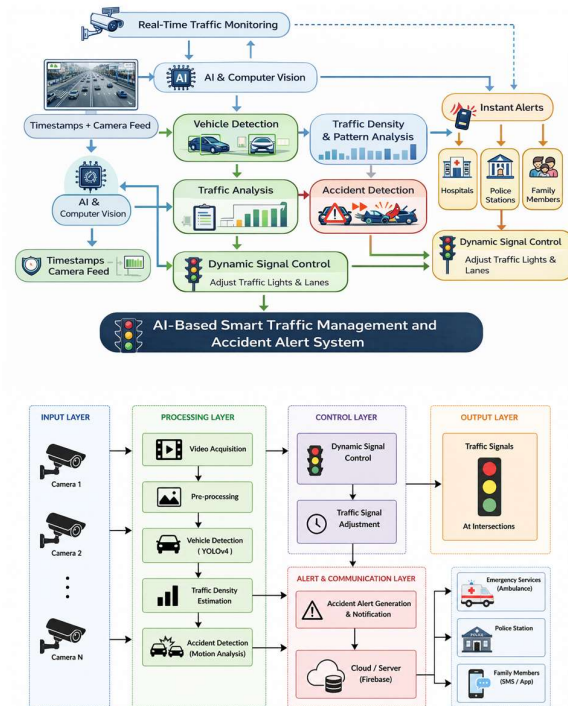


Fig. 1. System Architecture of the Proposed AI-Powered Smart Traffic Management and Accident Alert System

Fig. 1. System Architecture

VI. ALGORITHM

Algorithm 1: Smart Traffic Management

- 1) Capture video frames
- 2) Preprocess frames using OpenCV
- 3) Detect vehicles using YOLO
- 4) Count vehicles in each lane
- 5) Calculate traffic density
- 6) Adjust signal timing

- 7) Detect abnormal events
- 8) If accident detected:
 - Send alerts to hospital, police
 - Notify family members
- 9) Repeat process

VII. EXPERIMENTAL RESULTS AND ANALYSIS

To evaluate the performance of the proposed AI-Powered Smart Traffic Management and Accident Alert System, experiments were conducted using real-time traffic video datasets and simulated traffic scenarios. The system was tested for vehicle detection, traffic density estimation, accident detection, and alert generation. The evaluation is based on three key performance metrics: detection accuracy, response time, and traffic throughput.

A. Detection Accuracy

Detection accuracy refers to the ability of the system to correctly identify vehicles and detect accident events. The YOLO-based object detection model was trained and tested on traffic video datasets under varying lighting and environmental conditions.

The system achieved an average detection accuracy of more than 90%, demonstrating reliable performance in real-time scenarios. As shown in Fig. 2, the detection accuracy increases with the number of training epochs and stabilizes after reaching an optimal level, indicating proper model convergence.

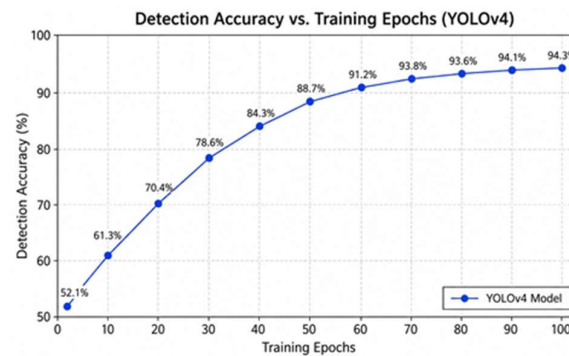


Fig. 4. Detection Accuracy vs. Training Epochs

Fig. 2. Detection Accuracy vs Training Epochs

B. Response Time Analysis

Response time is defined as the time taken by the system to detect an accident and send alerts to emergency services. In the proposed system, alerts are generated and transmitted using a cloud-based platform immediately after accident detection.

Experimental results show that the system can respond within less than 5 seconds, which is significantly faster compared to traditional manual reporting methods that may take several minutes. Fig. 3 illustrates the comparison between the response time of the proposed system and conventional systems.

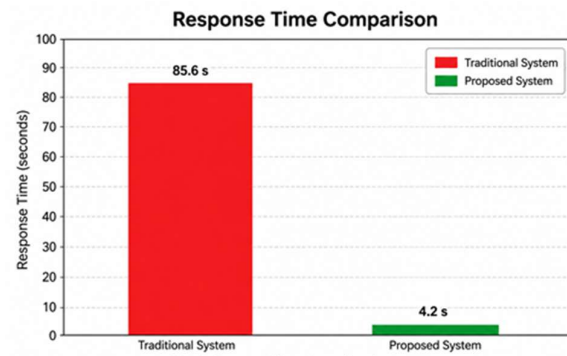


Fig. 5. Response Time Comparison between Proposed System and Traditional System

Fig. 3. Response Time Comparison

C. Traffic Throughput Improvement

Traffic throughput represents the number of vehicles passing through an intersection within a given time interval. The proposed system uses dynamic signal control based on real-time traffic density, which improves traffic flow efficiency.

The experimental results indicate an improvement of approximately 20–30% in traffic throughput compared to fixed signal timing systems. As shown in Fig. 4, the proposed system allows more vehicles to pass through the intersection by allocating green signal time dynamically based on traffic conditions.

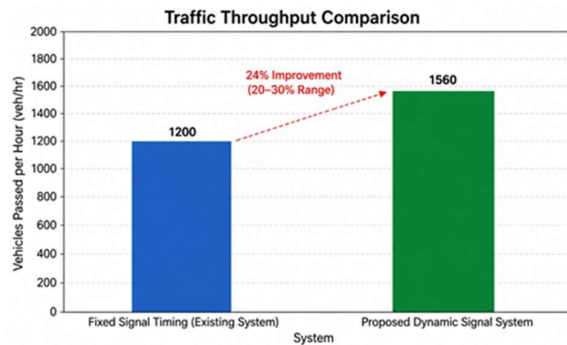


Fig. 6. Traffic Throughput Improvement: Proposed System vs. Fixed Signal Timing System

Fig. 4. Traffic Throughput Comparison

D. Performance Summary

The overall performance of the system demonstrates its effectiveness in handling real-time traffic scenarios. The integration of AI-based detection and intelligent signal control leads

to improved traffic flow, reduced congestion, and enhanced road safety.

The results clearly indicate that the proposed system out-performs traditional traffic management approaches in terms of accuracy, response time, and efficiency.

TABLE I
PERFORMANCE SUMMARY

Metric	Value
Detection Accuracy	> 90%
Response Time	< 5 seconds
Traffic Throughput Improvement	20–30%

VIII. COMPARATIVE ANALYSIS

To evaluate the effectiveness of the proposed system, a comparison is made with traditional and existing smart traffic management systems. The comparison is based on key features such as signal control, accident detection, alert mechanisms, and system integration.

TABLE II
COMPARISON WITH EXISTING SYSTEMS

Feature	Existing System	Proposed System
Signal Control	Fixed Timing	Dynamic (AI-Based)
Accident Detection	Manual Reporting	Automatic Detection
Alert System	Delayed Response	Instant Alerts
Traffic Monitoring	Sensor-Based / Manual	Camera + AI-Based
System Integration	Partial	Fully Integrated

The proposed system demonstrates significant improvements over existing methods by providing real-time decision-making, automated accident detection, and instant alert generation.

IX. CONCLUSION

This paper presented an AI-Powered Smart Traffic Management and Accident Alert System that integrates real-time traffic monitoring, dynamic signal control, and automated emergency response into a unified platform. The system utilizes computer vision and machine learning techniques to improve traffic flow and enhance road safety.

The experimental results indicate high detection accuracy, reduced response time, and improved traffic throughput. The integration of multiple functionalities into a single system reduces human intervention and ensures efficient traffic management.

Overall, the proposed system offers a scalable, efficient, and reliable solution for smart city applications and intelligent transportation systems.

X. FUTURE WORK

Future enhancements of the proposed system include the integration of autonomous vehicles for fully automated traffic management. Advanced deep learning models can be employed to further improve detection accuracy and system robustness. Additionally, real-time navigation assistance for drivers and integration with large-scale smart city infrastructure, including GPS and IoT-based tracking systems, can further enhance system performance and usability.

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