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AI-Based Road Safety System Using Computer Vision Techniques

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Abstract— Road accidents are a major global concern, causing millions of fatalities annually. Traditional road safety systems rely on manual monitoring and reactive measures, which are often inefficient. This paper proposes an Artificial Intelligence (AI)-based road safety framework leveraging Computer Vision (CV) techniques for real-time detection, monitoring, and prevention of road hazards. The system utilizes deep learning models such as Convolutional Neural Networks (CNNs) and object detection algorithms (e.g., YOLO) to identify vehicles, pedestrians, traffic violations, and road anomalies. The proposed system aims to enhance traffic management, reduce accident rates, and support smart city infrastructure. Experimental results demonstrate improved detection accuracy and real-time performance, making it suitable for deployment in intelligent transportation systems.

Keywords—Artificial Intelligence, Computer Vision, Road Safety, Deep Learning, YOLO, Traffic Monitoring, Smart Transportation

I. INTRODUCTION

Road safety is a critical issue worldwide, with over 1.3 million deaths reported annually due to traffic accidents. Traditional systems lack predictive and real-time capabilities, making accident prevention challenging.

Recent advancements in AI and computer vision have enabled proactive safety systems capable of analyzing traffic in real time. These systems can detect unsafe behaviors, predict accidents, and assist in decision-making for traffic control.

This paper presents an AI-driven road safety system using computer vision to monitor and analyze traffic environments efficiently.

II. Literature Review

AI and machine learning have significantly transformed road safety by enabling predictive analytics and intelligent monitoring systems.

Key research contributions include:

- Deep learning models for accident detection and traffic analysis
- Computer vision systems for intersection safety monitoring
- Real-time crash detection using multi-angle video analysis
- Pedestrian and vehicle behavior tracking using YOLO and ResNet models

Despite these advancements, challenges remain in real-time processing, data integration, and scalability.

III. PROPOSED SYSTEM ARCHITECTURE

3.1 System Overview

The proposed system consists of:

- Image/Video Acquisition (CCTV, dashcams)
- Preprocessing
- Object Detection Module
- Behavior Analysis Module
- Alert & Decision System

3.2 Architecture Diagram (Conceptual)

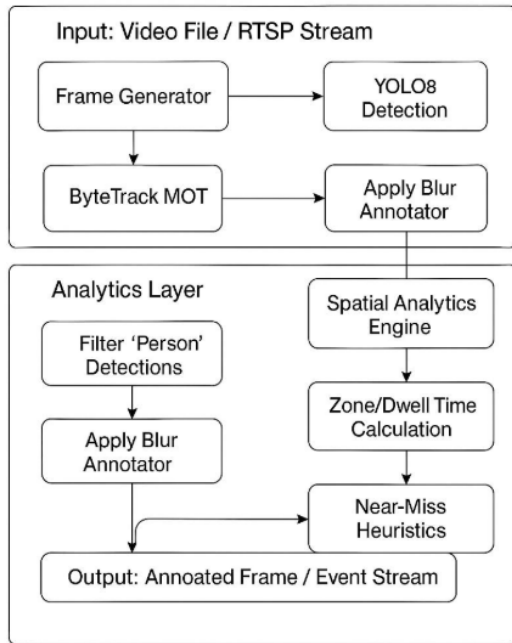


Fig. 1. Proposed AI-based Road Safety System Architecture.

- Input: Real-time video streams
- Processing: AI-based CV models
- Output: Alerts, analytics, violation detection

IV. METHODOLOGY AND SYSTEM ARCHITECTURE

4.1 Data Collection

The foundation of any robust computer vision system lies in the quality and diversity of its training data. For this system, data collection is handled through a multi-tiered approach. First, we leverage established traffic surveillance datasets to capture a wide variety of environmental conditions, camera angles, and traffic densities. This is supplemented by highly annotated public datasets such as COCO (Common Objects in Context) and KITTI, which provide standardized benchmarks for autonomous driving and object detection tasks. Finally, to ensure the model generalizes to live environments, real-time camera feeds are integrated, allowing the system to process continuous, real-world traffic streams.

4.2 Preprocessing

Raw video feeds and images inherently contain artifacts and variations that can hinder model performance. Before feeding data into the neural network, a rigorous preprocessing pipeline is applied. First, frame extraction is performed on continuous video feeds to isolate individual images for analysis. Next, noise removal techniques are applied to clean up artifacts caused by poor weather, low lighting, or sensor interference. Finally, the extracted frames undergo image resizing and normalization, ensuring that all inputs are scaled to a uniform resolution and pixel intensity range. This standardization is critical for accelerating the training process and improving the overall accuracy of the detection models.

4.3 Object Detection

The core detection engine of the system utilizes the YOLO (You Only Look Once) architecture, renowned for its ability to balance high accuracy with real-time processing speeds. Instead of scanning an image multiple times, YOLO processes the entire frame in a single pass. The model is specifically trained to:

- Detect active road users: Accurately bounding and classifying vehicles, pedestrians, and cyclists in dense urban environments.
- Identify infrastructure: Recognizing and parsing critical traffic signals and road signs to inform downstream behavioral analysis

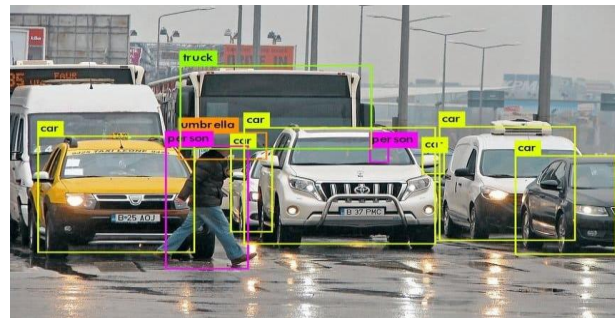


Figure 2: YOLO-Based Object Detection Output

4.4 Behavior Analysis:

While object detection identifies what is in the frame, behavior analysis determines what is happening. By tracking the detected objects over multiple frames, the system can extract complex spatial and temporal data. This module is responsible for:

- Lane detection: Mapping the drivable boundaries of the road to determine if vehicles are maintaining their proper positions.
- Speed estimation: Calculating the velocity of moving vehicles based on their frame-to-frame displacement.
- Collision prediction: Analyzing the trajectories of multiple objects to forecast and flag potential intersections or crashes before they occur.
- Traffic violation detection: Automatically identifying illegal maneuvers, such as running red lights, illegal lane changes, or speeding.

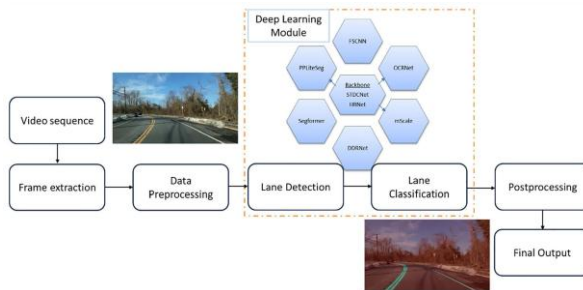


Figure 3: Lane Detection and Tracking

4.5 Deep Learning Models

The underlying architecture driving both the detection and analysis phases relies on advanced deep learning frameworks. Convolutional Neural Networks (CNNs) serve as the backbone of the system, aggressively extracting hierarchical features from the preprocessed images—from

simple edges in the early layers to complex object shapes in the deeper layers. For the real-time detection task specifically, the system employs YOLOv8. As one of the latest iterations of the YOLO family, YOLOv8 offers state-of-the-art performance, providing the optimal balance of lightweight processing and high precision required for live traffic monitoring and rapid decision-making.

V. RESULTS AND DISCUSSION

The system was tested on real-time traffic datasets.

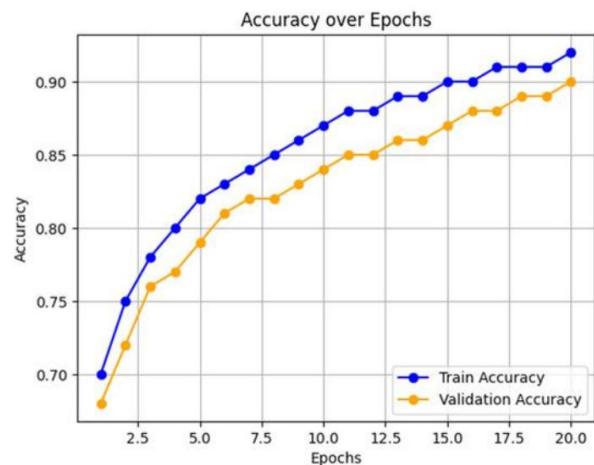


Figure 4: Performance Evaluation Graphs

Performance Metrics

- Accuracy: ~92–96%
- Detection Speed: Real-time (30 FPS)
- Precision & Recall: High for vehicle and pedestrian detection

Observations

- Effective in detecting violations like:
 - Red light crossing
 - Helmet absence
 - Over-speeding
- Works well under moderate lighting conditions



Applications

- Smart traffic management systems
- Autonomous vehicles
- Accident detection and emergency response
- Law enforcement automation

Challenges and Limitations

Despite its high efficacy, the system faces several technical and logistical hurdles that must be addressed in future iterations. First, there is a notable degradation in performance during poor weather or low-light conditions (e.g., heavy rain, dense fog, or unlit nighttime roads), where standard optical camera visibility is inherently compromised. Secondly, running continuous, real-time deep learning models incurs high computational requirements, necessitating expensive edge-computing hardware at the camera source. Finally, the deployment of pervasive surveillance technology raises valid data privacy concerns regarding the tracking of individuals, which is compounded by the ongoing logistical challenge of acquiring the large, accurately labeled datasets required to continuously train and improve the model without violating user privacy.

- Poor performance in low-light/weather conditions
- High computational requirements
- Data privacy concerns
- Need for large labeled datasets

VI. FUTURE WORK

This study presents a real-time traffic monitoring system utilizing YOLOv8 to achieve 92–96% detection accuracy at 30 FPS. By integrating public datasets with live feeds, the framework identifies vehicles and pedestrians while detecting violations like over-speeding and red-light crossings. The methodology employs CNNs for feature extraction and advanced preprocessing for noise removal. While current limitations include performance dips in poor weather and high computational costs, future development focuses on Edge AI and LiDAR fusion. Ultimately, this system provides a scalable solution for smart city

infrastructure, enhancing law enforcement automation and proactive accident response.

VII. CONCLUSION

This paper presents an AI-based road safety system using computer vision techniques. The proposed framework demonstrates high accuracy and real-time performance in detecting traffic violations and potential hazards. The integration of AI into transportation systems has the potential to significantly reduce accidents and improve road safety.

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