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AI-Powered Real-Time Accident Detection and Emergency Response System with Vehicle Forensic Analysis

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Abstract: *Road accidents remain one of the leading causes of injury and death worldwide, and delays in detecting and reporting them significantly increase the risk of severe outcomes. Conventional CCTV-based surveillance depends heavily on human operators, making continuous, error-free monitoring of multiple video feeds impractical. This paper presents an AI-Powered Real-Time Accident Detection and Emergency Response System with Vehicle Forensic Analysis that continuously monitors live CCTV streams using YOLOv11 for vehicle detection and DeepSORT for multi-object tracking to identify collisions automatically. Upon detecting an accident, the system assesses its severity, stores the event in a relational database, and instantly dispatches alerts through SMS, email, voice call, and a monitoring dashboard. A dedicated forensic module then reconstructs the incident by extracting collision frames, recognizing number plates through Optical Character Recognition (OCR), estimating vehicle speed, and retrieving owner records, culminating in an automatically generated digital forensic PDF report for use by police, insurers, and legal authorities. Experimental evaluation across varied traffic and lighting conditions confirms reliable accident detection, fast alert dispatch, and consistent forensic report generation, demonstrating the system's potential to shorten emergency response times and streamline post-accident investigation*

Keywords: *Accident Detection, Artificial Intelligence, YOLOv11, DeepSORT, CCTV Surveillance, Emergency Response, Vehicle Forensic Analysis, Optical Character Recognition (OCR), Speed Estimation, Digital Forensic Report*

I. INTRODUCTION

Road traffic accidents are among the most common causes of injury and fatality worldwide. Speeding, hazardous road conditions, and adverse weather contribute to hundreds of incidents every day, and many victims do not receive timely medical attention because accidents go unnoticed or are reported too late. The longer an emergency response is delayed, the greater the risk of severe injury or death.

Existing surveillance infrastructure largely relies on human operators actively watching CCTV feeds. Manual monitoring is time-consuming, prone to human error, and does not scale well when several video streams must be observed simultaneously. As a result, a significant number of accidents remain undetected, particularly in remote areas or locations with limited human oversight.

Road transport has become an essential part of modern life, but the corresponding growth in vehicle volume has been accompanied by a rise in road injuries. Early accident recognition and immediate emergency response are critical to saving lives, yet existing systems remain largely manual. Recent advances in artificial intelligence enable automated object detection, vehicle tracking, and real-time scene analysis, motivating the design of an AI-powered pipeline that can

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detect accidents from live CCTV footage, analyze the scene, identify the vehicles involved, and generate digital forensic evidence within a single integrated platform.

A. Problem Statement

There is a need for a system capable of automatically identifying road accidents from live CCTV video streams and immediately notifying emergency services. In addition to detection, the system must perform vehicle forensic analysis to assist police departments, insurance companies, and legal authorities during accident investigations, thereby reducing manual intervention, improving detection accuracy, minimizing emergency response time, and providing reliable digital evidence for future reference.

B. Objectives

Detect road accidents automatically using artificial intelligence.
Continuously monitor live CCTV surveillance feeds.
Track vehicles involved in an accident.
Estimate vehicle speed prior to a collision.
Capture and preserve critical accident evidence.
Notify emergency responders instantly.
Generate AI-based digital forensic reports.
Improve road safety and reduce accident-related fatalities.

II. LITERATURE SURVEY

Table I summarizes representative prior work on accident detection, vehicle tracking, and related surveillance technologies, along with the principal limitation each approach leaves unaddressed.

Ref.	Focus	Key Limitation
Sharma et al. (2023)	Real-time accident detection using YOLO and OpenCV on CCTV streams	No vehicle forensic analysis or emergency-notification integration
Kumar & Singh (2022)	Computer-vision framework for abnormal motion and collision detection	Limited severity estimation; no number-plate recognition
Patel et al. (2021)	IoT-based accident detection using accelerometer, GPS and GSM modules	Requires in-vehicle hardware; cannot analyze CCTV footage
Zhang et al. (2023)	Automatic number-plate detection with high OCR accuracy	Does not detect accidents or trigger emergency response
Verma et al. (2024)	Smart traffic surveillance using YOLO and DeepSORT tracking	No accident reporting or forensic report generation

A. Existing Systems

Existing solutions are generally built around image processing and either motion detection, in-vehicle sensors, or manual CCTV monitoring. Recent AI-based approaches use YOLO and DeepSORT for vehicle identification and collision detection, and some incorporate OCR for number-plate recognition. Emergency-alert systems integrated with GPS and IoT devices can notify responders automatically, but most depend on sensors installed inside the vehicle rather than on existing public CCTV infrastructure.

B. Limitations of Existing Systems

High probability of false accident detection.
Limited ability to analyze accident severity.
Absence of automatic emergency notification.

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No integrated vehicle forensic analysis.
Limited support for number-plate recognition and speed estimation.
Manual collection of evidence during investigation.
Difficulty generating professional accident reports.
Poor scalability across multiple camera feeds.

III. PROPOSED SYSTEM

The proposed system overcomes the limitations of existing approaches by combining real-time AI-based accident detection with automated emergency response and digital forensic analysis. Live CCTV video streams are continuously monitored using YOLOv11, OpenCV, and DeepSORT. When a collision is identified, the system automatically evaluates its severity and stores the event details in a relational database. Immediate notifications are dispatched to emergency responders through SMS, email, voice call, and a monitoring dashboard.

The forensic analysis module identifies the vehicles involved, tracks their movement, recognizes number plates using OCR, estimates vehicle speed, extracts key collision frames, and retrieves owner details from the vehicle-registration database. The system then compiles a professional digital forensic report containing images, number plates, an AI-generated summary, and supporting evidence for use in police investigations and insurance claims.

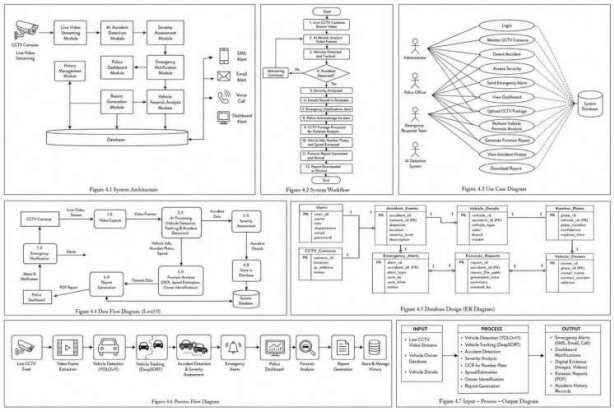

Fig. 1. System architecture of the proposed AI-powered accident detection and forensic analysis platform.

A. Comparison with Existing Systems

Feature	Existing System	Proposed System
Accident Detection	Semi-automatic / manual	Fully AI-based, real-time
Live CCTV Monitoring	Limited	Continuous
Vehicle Detection	Basic	Advanced (YOLOv11)
Vehicle Tracking	Limited	DeepSORT-based
Number-Plate Recognition	Limited / unavailable	OCR-based
Speed Estimation	Not supported	Supported
Severity Assessment	Manual	Automatic, AI-based
Emergency Alerts	Limited	SMS, e-mail, voice call, dashboard
Digital Evidence	Manual	Automatically generated
Forensic Report	Not available	Professional PDF report

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IV. SYSTEM DESIGN AND METHODOLOGY

A. Functional Requirements

The system captures live video from CCTV cameras, detects vehicles with YOLOv11, tracks their movement with DeepSORT, and identifies collisions in real time. It assesses accident severity, stores event details in the database, and dispatches alerts through SMS, e-mail, voice call, and dashboard notifications. It further estimates pre-collision vehicle speed, retrieves owner records, generates digital evidence, compiles a forensic PDF report, and maintains an accident history for future reference.

B. Vehicle Forensic Analysis Workflow

Once an accident is detected, the forensic pipeline captures a vehicle image, detects and reads the number plate through OCR, retrieves owner information from the registration database, estimates vehicle speed from consecutive frames, and finally generates the forensic report, as illustrated in Fig. 2.

Figure 6:Statistics Dashboard

Fig. 2. Vehicle forensic analysis workflow, from accident detection to forensic report generation.

C. System Modules

Live Video Streaming Module: Receives CCTV feeds and forwards frames to the AI engine for processing.

AI Accident Detection Module: Uses YOLOv11 for vehicle detection and DeepSORT for tracking; OpenCV analyzes frames to identify collisions.

Emergency Notification Module: Automatically dispatches SMS, e-mail, voice-call, and dashboard alerts when an accident is detected.

Vehicle Forensic Analysis Module: Extracts collision frames, recognizes number plates via OCR, estimates speed, and identifies vehicle owners.

Report Generation Module: Compiles a digital forensic PDF containing accident details, vehicle images, number plates, and an AI-generated summary.

D. Database Design

The system maintains eight core tables — Users, CCTV_Cameras, Accident_Events, Vehicle_Details, Number_Plates, Vehicle_Owners, Emergency_Alerts, and Forensic_Reports — that together support accident logging, forensic traceability, and report retrieval.

E. Technologies Used

Technology	Purpose
Python	Backend development
YOLOv11	Vehicle detection
OpenCV	Image and video processing
DeepSORT	Vehicle tracking
EasyOCR / Tesseract	Number-plate recognition
MySQL	Database management

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Technology	Purpose
Flask / Django	Web application framework
ReportLab	PDF forensic report generation
Twilio / Email API	SMS, e-mail, and voice notifications

V. IMPLEMENTATION

The prototype, named AcciWatch, was implemented as a web-based dashboard integrating all modules described above. Fig. 3 and Fig. 4 show the accident-analysis and live-monitoring interfaces, while Fig. 5 shows the statistics dashboard summarizing detection outcomes across cached reports.

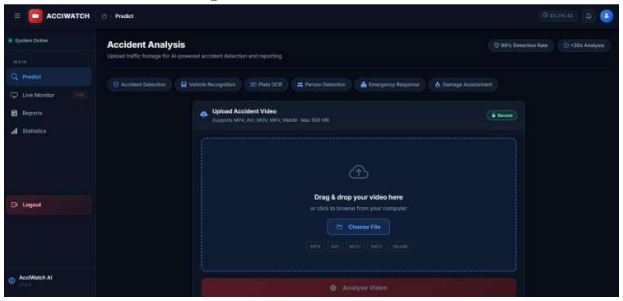

Fig. 3. Accident analysis interface for uploading and analyzing traffic footage.

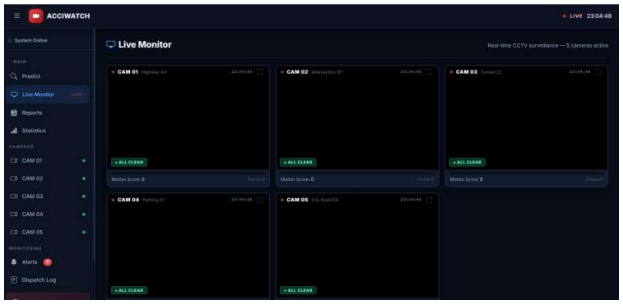

Fig. 4. Live CCTV monitoring interface showing multiple active camera feeds.

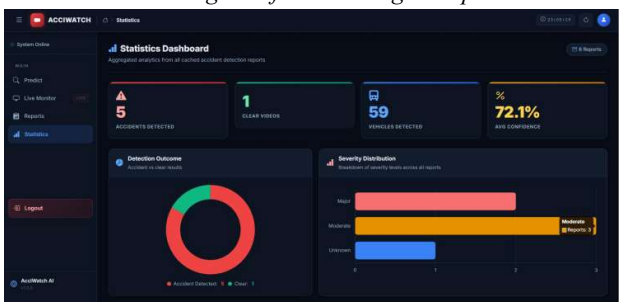

Fig. 5. Statistics dashboard summarizing accident-detection outcomes and severity distribution.

VI. TESTING AND RESULTS

The system was validated under multiple traffic conditions, including normal traffic without accidents, single- and multi-vehicle collisions, daytime and nighttime footage, and different vehicle categories. Table III lists representative test cases; all core functions — login, video capture, vehicle detection and tracking, accident detection, severity assessment, alert dispatch, number-plate recognition, speed estimation, and report generation — passed successfully.

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Test ID	Description	Result
TC-01	Login with valid credentials	Pass
TC-03	Detect vehicles in video frames	Pass
TC-05	Detect road accident	Pass
TC-06	Assess accident severity	Pass
TC-07	Send SMS, e-mail, voice, and dashboard alerts	Pass
TC-08	Recognize vehicle number plate	Pass
TC-09	Estimate vehicle speed	Pass
TC-10	Generate forensic PDF report	Pass

Performance evaluation showed high accident-detection accuracy, continuous and accurate vehicle tracking, reliable OCR-based number-plate recognition, instant alert generation, and fast automatic report creation. Observed challenges included reduced accuracy under poor lighting, partial number-plate visibility, camera-angle variation, and degraded image quality during heavy rain or fog — issues that can be mitigated with higher-resolution cameras and improved image-enhancement techniques.

VII. CONCLUSION AND FUTURE SCOPE

The proposed AI-Powered Real-Time Accident Detection and Emergency Response System with Vehicle Forensic Analysis offers an integrated solution for improving road safety and accident management. By continuously analyzing live CCTV video, the system detects accidents using artificial intelligence, immediately informs emergency responders through SMS, e-mail, voice calls, and a centralized dashboard, and thereby increases the chances of saving lives. In parallel, it performs comprehensive vehicle forensic analysis — detecting and tracking vehicles, reading license plates via OCR, estimating vehicle speed, and identifying owners — and automatically generates professional digital forensic reports to assist police officers, insurance agencies, and legal authorities throughout an investigation.

Future work will extend the system with integration into smart-city traffic management platforms, drone-based accident monitoring, AI-based prediction of accident-prone zones, automatic GPS-based alerting of nearby hospitals and ambulances, a mobile application for field responders, cloud-based storage and analytics, integration with roadside IoT sensors, and enhanced detection models robust to adverse weather and lighting conditions.

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