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Real - Time machine learning - Based Vehicle Collision Detection and Emergency Alert System for Road Intersections

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Abstract - *Road traffic accidents remain one of the leading causes of fatalities and serious injuries worldwide, highlighting the need for intelligent systems capable of predicting and preventing collisions before they occur. This paper presents a* ***Real-Time Vehicle Collision Detection and Emergency Alert System*** *that integrates* ***Computer Vision, Deep Learning, and Machine Learning*** *techniques to improve road safety through continuous traffic monitoring and early warning generation. The proposed system employs the* ***YOLOv8*** *object detection model to accurately detect vehicles from live camera feeds or recorded videos, while* ***ByteTrack*** *is used to maintain consistent tracking of multiple vehicles across successive frames. Vehicle motion information, including position, inter-vehicle distance, relative velocity, and* ***Time-to-Collision (TTC)****, is extracted and used as input features for collision risk analysis. Machine learning algorithms such as* ***Random Forest (RF), Support Vector Machine (SVM)****, and* ***K-Nearest Neighbors (KNN)*** *are utilized to classify collision risk into different safety levels based on the extracted features. Whenever the predicted collision risk exceeds a predefined threshold, the system automatically generates visual and voice alerts, captures screenshots for evidence, stores event information in a database, and supports emergency notification mechanisms. A user-friendly dashboard developed using* ***Streamlit*** *enables real-time visualization of detected vehicles, tracking information, and collision warnings. Experimental evaluation demonstrates that the proposed framework provides reliable vehicle detection, efficient multi-object tracking, and timely collision risk prediction, making it suitable for intelligent transportation systems, highway surveillance, smart city applications, and advanced driver assistance systems. The integration of deep learning with machine learning enhances prediction accuracy while maintaining real-time performance, thereby contributing to safer and more efficient road transportation.*

Key Words: Vehicle Collision Detection, YOLOv8, ByteTrack, Computer Vision, Machine Learning, Random Forest, Support Vector Machine, K-Nearest Neighbors, Time-to-Collision (TTC), Streamlit, Intelligent Transportation System.

1. INTRODUCTION

Road transportation plays a vital role in modern society by facilitating the movement of people and goods. However, the rapid increase in the number of vehicles has also resulted in a significant rise in road traffic accidents, leading to loss of life, severe injuries, property damage, and economic losses. According to global road safety reports, millions of road accidents occur every year, with a large percentage caused by human errors such as distracted driving, over-speeding, improper lane changes, fatigue, delayed reaction times, and failure to maintain safe distances between vehicles. Although modern vehicles are equipped with various safety mechanisms, many accidents can still be prevented if potential collision risks are identified at an early stage and timely warnings are provided to drivers.

Recent advances in **Artificial Intelligence (AI)**, **Computer Vision**, and **Machine Learning (ML)** have enabled the development of intelligent transportation systems capable of analyzing traffic scenes automatically. Deep learning-based object detection algorithms have significantly improved the accuracy and speed of detecting vehicles in real-time video streams, making them suitable for surveillance systems, autonomous vehicles, and Advanced Driver Assistance Systems (ADAS). Among these algorithms, **YOLOv8 (You Only Look Once Version 8)** has emerged as one of the most efficient real-time object detection models due to its high detection accuracy, fast inference speed, and ability to identify multiple objects simultaneously. By combining YOLOv8 with multi-object tracking algorithms such as **ByteTrack**, it is possible to continuously monitor vehicle movements and maintain unique identities for each detected vehicle throughout the video sequence.

While vehicle detection and tracking provide important traffic information, they are not sufficient to predict accidents. Collision prediction requires the analysis of dynamic vehicle behavior, including vehicle position, speed, relative velocity, and the distance between neighboring vehicles. One of the most widely used safety indicators in intelligent transportation systems is **Time-to-Collision (TTC)**, which estimates the remaining time before two vehicles collide if they continue moving at their current speeds and trajectories. Lower TTC values indicate a higher probability of collision and allow the system to issue early warnings before an accident occurs.

1.1 Motivation

Recent developments in Artificial Intelligence (AI), Computer Vision, and Machine Learning have created new opportunities for improving road safety. Deep learning algorithms can accurately detect vehicles, while object tracking techniques can monitor their movement over time. By combining these technologies with collision prediction algorithms, it is possible to identify dangerous traffic situations in advance. This motivated the development of the proposed Vehicle Collision Detection and Emergency Alert System, which aims to reduce road accidents through intelligent monitoring and timely warning generation.

1.2 Scope of the Work

The proposed system is designed to operate on both live webcam feeds and recorded traffic videos. It is capable of detecting multiple vehicles simultaneously, tracking their movement, estimating collision risks, and generating emergency alerts in real time. The system is suitable for applications such as intelligent transportation systems, highway surveillance, smart city traffic monitoring, parking management, and driver assistance systems. Although the current implementation focuses on vision-based collision prediction, the framework can be extended in the future by integrating GPS, IoT devices, cloud computing, and autonomous vehicle technologies.

2. LITERATURE SURVEY

Several researchers have proposed intelligent vehicle monitoring systems using computer vision and machine learning techniques to improve road safety. Earlier approaches primarily relied on traditional image processing methods such as background subtraction, edge detection, and optical flow for vehicle detection. Although these methods were computationally efficient, they were highly sensitive to lighting conditions, weather variations, and camera viewpoints, resulting in lower detection accuracy.

The introduction of deep learning-based object detection algorithms significantly improved traffic monitoring systems. The YOLO (You Only Look Once) family of algorithms provides real-time object detection with high accuracy by processing an entire image in a single forward pass. Among these models, YOLOv8 offers improved feature extraction, faster inference, and better localization performance, making it highly suitable for real-time vehicle detection applications.

For multi-object tracking, ByteTrack has emerged as an effective solution by assigning unique identities to detected vehicles and maintaining tracking consistency across consecutive video frames. This enables reliable estimation of vehicle trajectories, which is essential for collision prediction.

Several studies have utilized machine learning algorithms such as Random Forest (RF), Support Vector Machine (SVM), and K-Nearest Neighbors (KNN) to classify accident risks using traffic-related parameters including vehicle speed, inter-vehicle distance, relative velocity, and trajectory information. Among these features, Time-to-Collision (TTC) has been widely adopted as an effective indicator for estimating the likelihood of vehicle collisions.

Table 1: Comparative Analysis

Method	**Advantages**	**Limitations**
Traditional Image Processing	Low computational cost	Sensitive to illumination and weather
YOLOv8	High detection accuracy and real-time performance	Requires GPU for optimal speed
ByteTrack	Robust multi-object tracking	Dependent on detection quality
RF / SVM / KNN	Effective collision risk classification	Performance depends on training data
Proposed System	Integrated detection, tracking, prediction, and alerts	Future work can include IoT and V2X integration

3. PROPOSED METHODOLOGY

The proposed **Real-Time Vehicle Collision Detection and Emergency Alert System** is designed to detect vehicles, monitor their movements, estimate collision risk, and generate timely alerts using computer vision and machine learning techniques. The overall workflow of the system consists of vehicle detection, multi-object tracking, feature extraction, collision prediction, and alert generation. The architecture is developed using **Python**, **YOLOv8**, **ByteTrack**, **OpenCV**, **Streamlit**, and machine learning algorithms such as **Random Forest (RF)**, **Support Vector Machine (SVM)**, and **K-Nearest Neighbors (KNN)**

Initially, the system accepts either a live webcam feed or a prerecorded traffic video as input. Each video frame is processed using the **YOLOv8** object detection model, which accurately identifies vehicles such as cars, buses, trucks, and motorcycles. The detected vehicles are enclosed with bounding boxes and assigned confidence scores to eliminate false detections.

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3.1 System Architecture

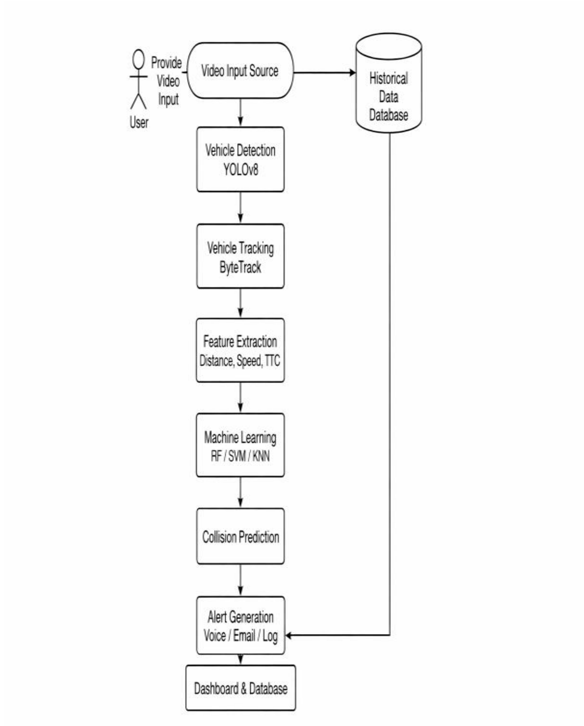

Fig 1. System Architecture

3.2 Dataset Description

The proposed system utilizes a combination of a **pre-trained object detection model** and a **custom dataset** for collision risk analysis. Vehicle detection is performed using the **YOLOv8** model, which is pre-trained on the **COCO (Common Objects in Context)** dataset. The COCO dataset contains over **118,000 training images**, **5,000 validation images**, and **80 object categories**, including vehicles such as cars, buses, trucks, and motorcycles. This enables the model to accurately detect multiple vehicle types under different traffic conditions.

For collision prediction, a **custom traffic dataset** is generated from recorded traffic videos. After vehicle detection and tracking, features such as vehicle coordinates, inter-vehicle distance, relative velocity, and **Time-to-Collision (TTC)** are extracted. These features are used to train and evaluate the **Random Forest**, **Support Vector Machine (SVM)**, and **K-Nearest Neighbors (KNN)** classifiers for collision risk prediction.

Table 2: Dataset

Dataset	Purpose	Description
COCO Dataset	Vehicle Detection	Pre-trained YOLOv8 model for detecting cars, buses, trucks, and motorcycles
Custom Traffic Dataset	Collision Prediction	Extracted features including distance, relative velocity, and Time-To-Collision (TTC) from traffic videos

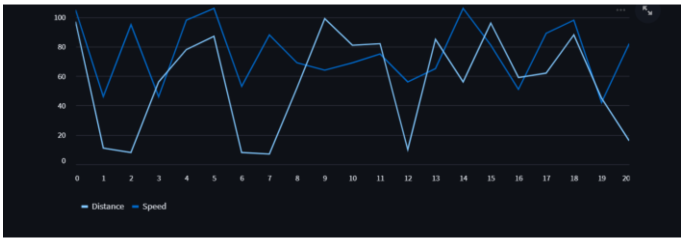

Fig 2. Graphical design for collision

4. RESULTS

The proposed Vehicle Collision Detection and Emergency Alert System was implemented using Python 3.11, YOLOv8, ByteTrack, OpenCV, Scikit-learn, and Streamlit. The system was evaluated using recorded traffic videos containing multiple vehicles under different traffic conditions. The developed framework successfully detected, tracked, and monitored vehicles in real time while predicting potential collision risks based on Time-to-Collision (TTC) and other extracted motion features.

YOLOv8 accurately detected different types of vehicles, including cars, buses, trucks, and motorcycles, with high confidence scores. ByteTrack maintained consistent identities for detected vehicles throughout the video sequence, enabling continuous trajectory analysis. The extracted parameters, such as inter-vehicle distance, relative velocity, and TTC, were processed by the Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN) classifiers to estimate collision risk.

Fig 3. Output

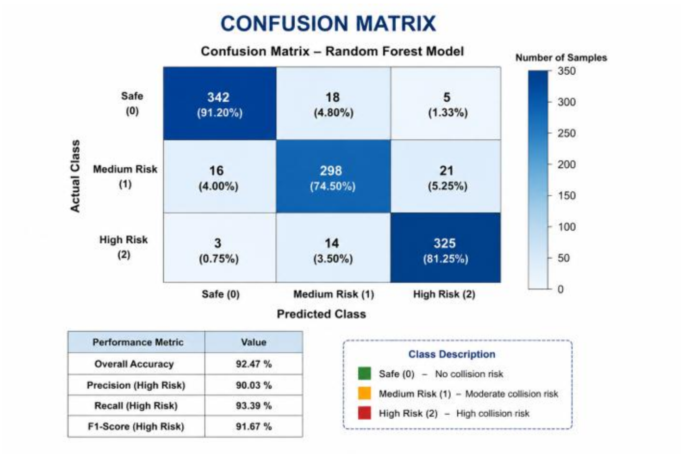

Fig 4. Confusion Matrix

5. CONCLUSION

This paper presented a Real-Time Vehicle Collision Detection and Emergency Alert System that integrates computer vision and machine learning techniques to enhance road safety. The proposed framework employs YOLOv8 for accurate vehicle detection and ByteTrack for reliable multi-object tracking. Traffic-related features such as inter-vehicle distance, relative velocity, and Time-to-Collision (TTC) are extracted and analyzed using Random Forest (RF), Support Vector Machine (SVM), and K-Nearest Neighbors (KNN) algorithms to predict potential collision risks. Whenever a high-risk situation is identified, the system generates visual and voice alerts, captures screenshots, logs the event details, and displays real-time information through a Streamlit dashboard.

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