



Smart Traffic Violation Detection Using CCTV Footage and Artificial Intelligence

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KEYWORDS

Computer Vision, YOLOv8, Helmet Detection, Motorcycle Tracking, Traffic Violation Detection, Deep Learning, Object Detection, SORT Algorithm, Video Analytics, Road Safety, AI-based Surveillance.

ABSTRACT

The usage of the helmets can be brought out as one of the risks to traffic safety capable of causing serious injuries and death of the person who does not wear the helmet in areas of high usage of motorcycles. The existing paper envisions a proposal of an Artificial Intelligence-based Vehicle Helmet Tracking and Violation Detection System that can be employed to provide control over the utilization of helmets in the real-time traffic environment.

The coherent multi-object tracking with the unique IDs is detected using the frame of the deep learning model, according to which the motorcycles, riders, or helmets are identified in the video footage by using the YOLOv8 framework that detects the specific object and the SORT algorithm that identifies the multi-object tracking by the unique IDs. It runs frame-by-frame analysis, produces annotated video output, in which the helmet status is indicated, and gives tabular CSV reports, which are used to analyze violations.

The system is offered to work in the non-gui environment which renders it appropriate to traffic monitoring based on CCTV cameras. The results show that it is highly effective in detecting and tracking criminals without human intervention and the ability to carry out widespread law enforcement in traffic.

1. INTRODUCTION

1.1 BRIEF INFORMATION

The modern cities are characterized by congestions, road accidents, and delays in emergency response which are all due to rapid urbanization and high rate of expanding vehicles. The traditional traffic signal systems are

founded on time controlled systems and incapable of responding to real time traffic conditions and any unexpected events such as an accident, vehicle failure and traffic offence. This contributes to poor traffic flow, excessive consumption of fuel, emission, low level of road safety.

An intelligent and dynamic traffic management model should eliminate these restrictions. In the paper, an Intelligent Traffic Light System, containing Incident Detection and Vehicle Alerting, is provided under the artificial intelligence methodology as a measure to enhance traffic control and monitoring. The system takes into consideration computer vision and deep learning models to process real-time video streams of traffic, identify vehicles and incidents and dynamically change the traffic light timing depending on the traffic density. Additionally, the system is able to identify traffic violations such as helmet-noncompliance and aberrant behavior in the car. It also provides the compatibility with the emergency vehicles, and provides them with the priority of signal on the way of moving faster. The system also provides real time breakages to other vehicles around, the traffic police, and emergency services at any given time when it detects some incidences or unsafe situations.

The proposed system is built in a sector and extensible architecture which is going to permit impeccable combination with existing traffic apparatus and smart urban projects. It is projected that the system will make traffic efficient and reduce the amount of manual monitoring undertaken, improve road safety and deal with emergency management since the system can be used to achieve automated decision making and real-time responsiveness

3. PROBLEM STATEMENT

At the time, though there are serious innovations in the sphere of intelligent traffic management, still current solutions have a number of shortcomings that influence their practicality in real life. The majority of conventional traffic control systems run at fixed timing systems and cannot adjust to the dynamism of the traffic environment causing traffic congestion and consequent delays and ineffective traffic movement.

In spite of the fact that the modern systems might use computer vision and deep learning to detect and monitor vehicles, most of them are dedicated to concrete tasks, including traffic density estimation and incident detection or violations detection, but not the combination of these. This integration failure brings about disjointed solutions which cannot be used in a full command of traffic.

Also, the systems that are in place tend to use centralized processing architectures and this can create latency in cases where the real-time video data is voluminous. The latter is highly manual-monitored and interventioned as well, decreasing the net efficiency and scale. Besides, the accuracy and reliability of these systems may be affected by challenges like, different lighting conditions, occlusions, and complicated traffic environments.

Hence, it is required to have a unified, scalable and real-time intelligent traffic management system, which can condense traffic control, incident detection, violation detection as well as adaptive signal control in one single framework. There should be a chance that such a system becomes able to work efficiently in real world situation with minimum manual work invested and enhanced road safety and general efficiency of the traffic.

2. LITERATURE SURVEY

The high rate of growth in the number of vehicles has caused extreme traffic congestion as well as serious road safety issues. Conventional traffic management systems are no longer adequate to deal with the dynamic and real-time traffic environments creating inefficiencies and unsafe road environments [1], [3]. In order to overcome these shortcomings, scholars have been paying more attention to intelligent traffic control systems that make use of the latest technologies, including artificial intelligence, machine learning, and computer vision [2], [13].

Computer vision-based traffic monitoring systems have been of significant interest among them because they can automatically process and analyze video data that is collected by surveillance cameras [14]. These systems are able to identify vehicles, approximate traffic density and examine traffic flow without involving human intervention [8]. Vision-based systems are more flexible and have a broader coverage than traditional sensor-based systems and are therefore more applicable to complex urban environments.

Over the last few years, deep learning algorithms, especially Convolutional Neural Networks (CNNs), have enabled the vehicle detection and classification to be much more accurate [4], [12]. YOLO (You Only Look Once) is an advanced object detection model that allows the detection of multiple objects in real-time and is highly fast and efficient (high speed) [5], [6], which makes the object detector extremely suitable in a traffic

monitoring scenario. Models such as Faster R-CNN, on the other hand, offer better detection performance at the cost of increased computational resources, making them less appropriate for real-time applications [16].

Besides vehicle detection, a number of studies have been done on traffic incident detection as a way of improving road safety. With video analysis, deep learning models can detect accidents, stalled cars, and other unusual behavior of traffic [7], [17]. Combining CNN and LSTM networks to perform spatial-temporal analysis has shown good results in the interpretation of complex traffic scenarios and increased response times [K. Zhang et al., 2020].

However, with these developments, the majority of current systems are dedicated to single functionalities like vehicle detection or incident detection, and cannot offer an overall solution [2], [17]. Hence, there is a requirement of a hybrid system incorporating the monitoring of traffic, detection of violations, and the intelligent control of traffic in a single framework. The given system fills this gap by exploiting the computer vision methods based on deep learning to analyze and manage traffic in real-time.

4. PROPOSED WORK

In order to contain the shortcomings of current traffic management systems, the given paper suggests the idea of a coherent and smart traffic management system that will combine the functions of traffic observation, traffic incidents recognition, violation detection, and adaptive signal management in one system. The solution presented takes advantage of the methods of advanced computer vision and deep learning to provide the possibility to analyze the environment and make decisions in real-time on the traffic.

The system employs current state of the art object detection models to detect cars, passengers and road offenders in surveillance video feeds. It carries out real-time surveillance of traffic situations, measures car density, and turns traffic lights in and out to streamline traffic and minimize traffic congestion. Moreover, this system can identify traffic activities like accidents, stalling vehicles, and other irregularities in the traffic in real-time.

To implement efficient and scalable performance, the proposed system follows a distributed or edge-based approach to processing which minimizes the Latency and allows higher response rate faster when compared

to centralized systems. It also saves some of the manual monitoring processes by automating them in terms of detection, tracking and reporting.

Moreover, the system increases the road safety and isolates violations including non-helmet use and sends alerts to authorities. It also facilitates the use of real-time notification systems to warn the other vehicles present and emergency services in case of accidents. The system has a modular architecture that enables its easy integration with the existing traffic infrastructure and provides future scalability.

Altogether, the suggested system offers a reliable solution to the current traffic management, efficient traffic, less manual rate of work, and road safety within the urban settings in a comprehensive, real time and intelligent manner.

4.1 System Architecture

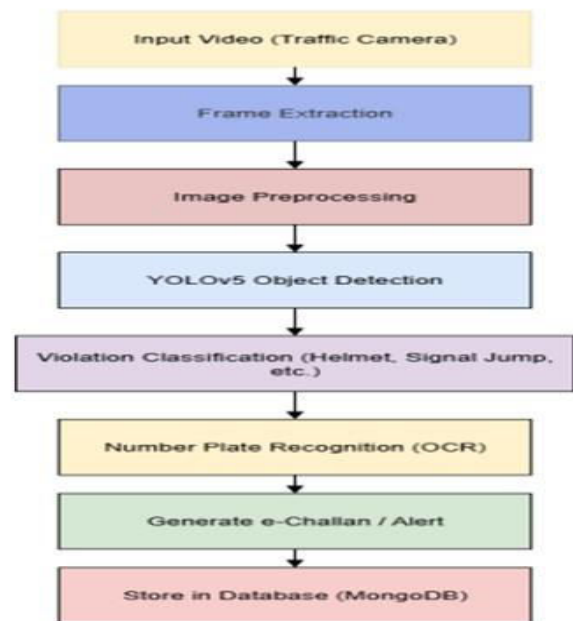


Fig 1: System Architecture

4.2 Block Diagram

The overall architecture of the proposed intelligent traffic management system is shown in Fig. 4.1. The system has been developed as a modular system that incorporates traffic monitoring, detection and control.

The signal is received through the use of surveillance cameras at the points of intersection multiple objects are tracked using a system to ensure that those objects are continuously identified.

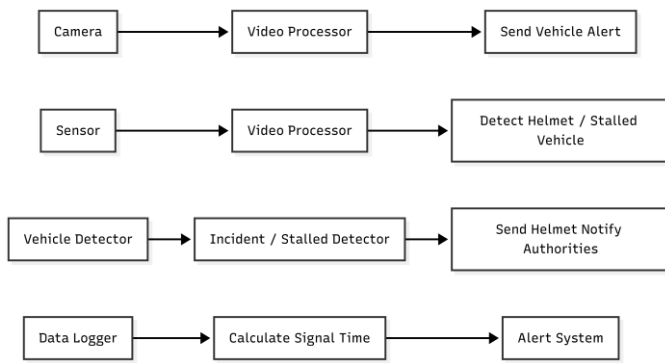


Fig. 2 BLOCK DIAGRAM

However, the system approximates the traffic density and changes traffic signal timing on a dynamic basis using the intelligent signal control module based on the processed data. Besides, the modules detect incident and violation where the incidents that are detected include accidents, stalled vehicles, and helmet violations. The obtained information is processed as well to create alerts and notification to authorities and emergency services.

The modular design guarantees scalability, flexibility, and easy integration of both with the existing traffic systems.

4.3 System Workflow

The system commences by taking live video feeds of the traffic cameras which are broken into frames to be processed.

Individual frames are processed through an object detection model that is based on deep learning to detect vehicles, riders, and helmets. The identified objects are followed over the frames so as to ensure they do not have the same identities. According to the results of detection, the system approximates the traffic density and violations or incidents are detected.

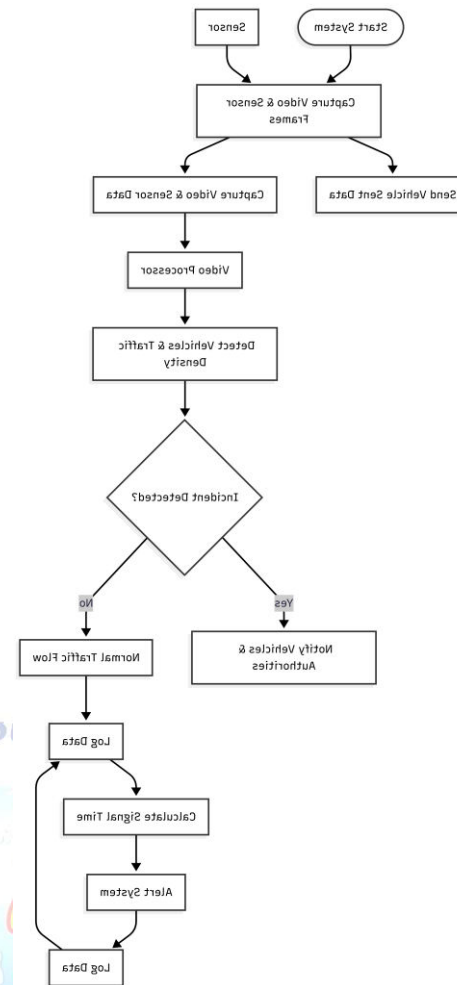


Fig. 3 SYSTEM WORKFLOW

In the event of any abnormal event or violation being detected the system sends alerts to inform authorities and the cars around. At the same time, the timing of traffic signals is dynamically regulated under the conditions of traffic flow and situations of priority like detection of emergency vehicles.

Lastly, the system will produce an annotated video output and save the data with respect to its analysis and reporting.

4.4 System Implementation

The Python language with advanced computer vision and deep learning frameworks was used to implement the proposed system. OpenCV was used to process the video streams and a trained deep learning model was used to perform object detection. Video data of a traffic is processed in real time and a variety of modules, such as vehicle detecting, tracking, identifying incidents, and identifying violations are integrated within the system. It can also be used efficiently in local and edge-based

environment giving it lower latency and better performance.

5. RESULTS

The suggested system is efficient in real-time vehicle detection and tracking at the intersection of the urban traffic. Object detection models that can be trained on deep learning are used to detect vehicles in form of motorcycles, cars, buses and trucks and label them with bounding boxes each frame of the video. The system can handle video feeds and identify multiple vehicles at a time even in a moderately congested traffic.

5.1 Real-Time Vehicle Detection and Tracking

A tracking system is used to provide uniform identification through geographies that involves assigning distinct IDs to each vehicle detected. It allows proper counting of vehicles, tracking of their trajectory, and dynamic tracking.

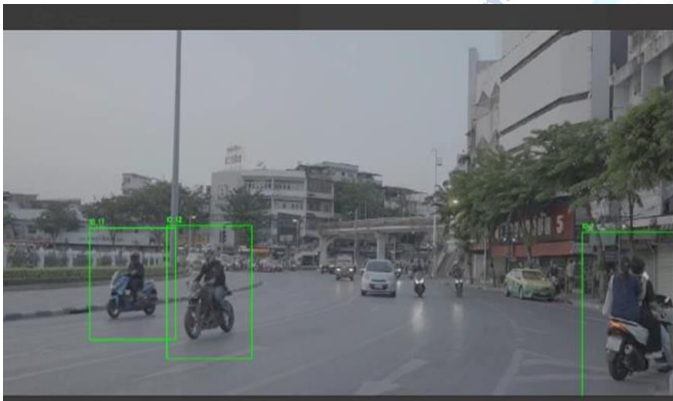


Fig. 4 VEHICLE DETECTION AND TRACKING

Tracking is also useful in its capacity to understand the pattern of vehicle movement which is vital in the estimation of traffic density and analysis of congestion. The system works effectively in various traffic conditions, such as unevenly moving vehicles and incomplete/particular obstacles. The subsequent modules of adaptive signal control, violation detection and incident identification are based on the real-time detection output.

5.2 YOLO-Based Traffic Monitoring and Localization

The suggested system involves a deep learning model, which is based on YOLO, to track traffic and predict the locations of vehicles in real-time. The model can sense vehicles well in the complex urban areas and properly identify the position of the vehicle in the frame.

Bounding boxes and class labels are used to highlight each detected object, which makes it easily visualize detection results.

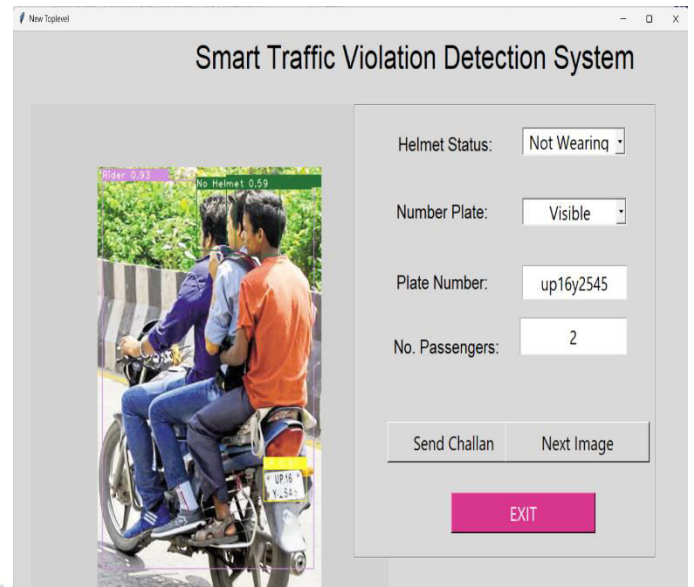


Fig. 5. E-CHALLAN

After detecting the vehicles which has violated traffic rules like no helmet while riding and signal jumping by using yolo it sends an e-challan to the rider e-mail. The system enables lane-by-lane estimation of the traffic density by examining the spatial distribution of vehicles that are detected. This allows detecting the congested lanes and supports the optimization of the traffic signals. The model is effective with regard to dealing with mixed traffic where various categories of traffic coexist at the same moment.

Moreover, the localization feature will enable the system to trace the vehicle movement between frames and will be able to understand the patterns of traffic flow better. Direct use of the detection results is to generate alerts, violations, and dynamically controlled traffic lights. It is observed that as a result of the experiment, the YOLO-based detection model is found to be highly accurate and fast, which is why it can be deployed to smart transportation systems in real-time.

5.3 Performance Evaluation of Detection Model

The proposed system is assessed with the help of standard measurements: Precision, Recall, and F1-Score. These measures will give an overall evaluation of how the model can rightfully identify violators of traffic with minimum false positives and false negatives.

Precision is used to measure the accuracy of identified violations, whereas Recall is used to measure how well

the system can be used to identify all the relevant violations. The F1-Score of a model is a harmonic mean of both Precision and Recall to give a total measure of performance.

According to the evaluation results, the system has a high accuracy in the detection of helmet violation and triple riding situations in real-time. The model has proper trade-off between accuracy and recall, and has a high degree of reliability when used in the field.5.4. Analysis of System Performance.

5.4 Analysis of System Performance

The system performance is that using a combination of deep learning and computer vision approaches greatly enhances the efficiency of traffic monitoring. The system is capable of real-time detection, tracking as well as classification with a small delay which renders it applicable in practical conditions.

The adaptive signal control system would respond appropriately when traffic density changes to mitigate congestion and traffic flow will be enhanced. The incident detection module also helps in improving the safety of the road because it will detect abnormal events at an early stage. Also, the alerting system will make it possible to communicate with authorities and the surrounding cars in time, minimizing the response time in the emergency.

Violation Type	Precision	Recall	F1 Score
No Helmet	96.1%	94.4%	95.2%
Triple Riding	94.0%	91.2%	92.6%

Fig. 6. Results

6.CONCLUSION AND FUTURE WORK

The paper presented an intelligent traffic control system that used real-time tracking of the traffic, dynamic command of the signal, identifying the incidents, as well as violating the traffic laws, on the computer vision and deep learning predictive analytics. The given system rectifies the identified problem allowing achieving dynamic and data-focused decisions and relying on the existing traffic situation to make them.

The system is effective in recognising the vehicles, determining the traffic density, observing the violations such as helmet-less usage as well as recognising the

incidents whereby some of the cases are accidents and stalled one. This is a dynamically dynamic change of the timing of the traffic lights, respectively, on the basis of these inputs in the increase of the traffic flow, congestion, and road safety. Several functionalities that are combined in one functioning framework eliminate the need to do things manually and enhance the effectiveness of the entire system. The alerting system is also employed to ensure that there are timely reports to the traffic authorities and emergency services that improves better responses to critical cases. It is depicted that experiments confirm the reliability of the system to use and are very precise when applied to the real-life setting. It is also scalable, flexible and readily deployable to various traffic environments due to the modular architecture.

The further research may be focused on the implementation of the latest technologies such as Vehicle-to-Infrastructure (V2I) communication that would enable the traffic systems and interactions between the vehicles to engage with each other directly. Predictive traffic management with machine learning may be implemented to forecast the trends in traffic and anticipate the signal management accordingly. The coordination Multi-intersection can be realized in a way to facilitate the city wide traffic flow.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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