Development of Traffic Rules Violation Detection System

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Abstract- *Traffic signal violations are a major contributor to road accidents and traffic congestion. Therefore, developing an automated system to detect traffic signal violations is crucial to improve road safety and traffic management. In this paper, we propose a real-time traffic signal violation detection system that uses computer vision techniques to identify signal jump and speed limit violations. Our system's architecture includes cameras or drones to capture video footage, YOLOv7 object detection algorithm to detect vehicles and their location, optical flow to calculate vehicle speed, and temporal logic to identify signal jump violations. We tested our system on various datasets, including different weather conditions and camera angles, and achieved an accuracy rate of 90%. The system's processing time is less than 200 milliseconds per frame, making it suitable for real-time applications. Our proposed system can contribute to improving road safety and traffic management by detecting traffic signal violations automatically and efficiently.*

Keywords- YOLO, temporal, detection, classification, threshold, dilation, contour.

I. INTRODUCTION

Traffic signal violations pose a significant problem globally, resulting in numerous accidents and fatalities on roads. Traffic signals are intended to regulate traffic flow and prevent collisions by allocating right-of-way to different directions at intersections. However, in many instances, drivers disregard traffic signals due to carelessness or recklessness, which can have serious implications for road safety and traffic management. Running a red light, for instance, can lead to a head-on collision with cross traffic or a side-impact crash with pedestrians or cyclists. Similarly, ignoring a stop sign can cause a rear-end collision with following vehicles or a T-bone crash with crossing vehicles. These types of accidents can cause severe injuries or fatalities to the drivers and other road users involved. Furthermore, traffic signal violations can also disrupt traffic systems' smooth operation and increase congestion and delays on roads. Hence, it is critical to comprehend the reasons and impacts of traffic signal violations and devise effective methods to prevent them.

II. MOTIVATION

Traffic signal violations pose a significant challenge to road safety and traffic management worldwide. As such, it is crucial to develop an efficient and automated system that can detect and prevent these violations. By utilizing computer vision techniques, we can create a reliable system that can accurately detect and identify vehicles that violate traffic signals, allowing authorities to take appropriate measures to avoid future accidents and fatalities [1]. Moreover, such a system can provide valuable data and insights on the patterns and causes of traffic signal violations, which can help inform and shape better policies and interventions. Furthermore, a computer vision-based system can offer distinct advantages over other detection methods such as cameras or sensors, in terms of cost-effectiveness, scalability, and dependability. Consequently, our research endeavours to develop and assess a unique and innovative computer vision-based system for detecting traffic signal violations.

III. OBJECTIVES

The primary aim of our system is to detect and identify traffic signal violations, such as signal jump and speed limit exceedance, through the use of computer vision techniques. Our system's sub-objectives involve achieving high accuracy rates, fast processing times, and robustness to handle various weather conditions, camera angles, and scenarios. These sub-objectives are:

- Developing a computer vision algorithm that can accurately detect and track vehicles in real-time by analyzing video streams from traffic cameras.
- Creating a computer vision algorithm that can identify and classify traffic signals using color and shape features.
- Developing a computer vision algorithm that can measure vehicle speed and distance through optical flow and perspective transformation techniques.
- Designing a computer vision algorithm that can identify traffic signal violations based on a vehicle's position, speed, direction, and signal state.

- Evaluating the system's performance through various metrics such as processing time, F1-score, recall, and precision.

These sub-objectives will allow us to develop an effective and efficient computer vision-based system for detecting traffic signal violations, which can significantly enhance road safety and traffic management.

IV. SCOPE

Our system is designed to automatically and efficiently detect traffic signal violations using video footage captured from cameras mounted at intersections. To achieve this, we utilize the YOLOv7 object detection algorithm, which is a well-known deep learning model for object detection. This algorithm is trained to identify and locate vehicles in each frame of the video stream, using a bounding box and a confidence score. We also apply optical flow techniques to estimate the speed and distance of each vehicle, which is a critical component for identifying speed limit exceedance violations.

Additionally, we use temporal logic to detect signal jump violations. This involves analyzing the sequence of traffic signal states and vehicle positions over time. We closely monitor the traffic signal state and the position and speed of each vehicle as it approaches the intersection. If a vehicle crosses the stop line when the traffic signal is red or yellow, or if it fails to stop at a stop sign, we consider it as a signal jump violation.

Our system requires high-performance computing hardware and software to process the significant amount of data involved in real-time. We utilize powerful CPUs and GPUs, along with parallel processing and caching techniques, to ensure rapid and accurate detection and classification of traffic signal violations. We also conduct thorough testing and validation of the system using different datasets and performance metrics to ensure its reliability, accuracy, and robustness under different scenarios and conditions. Ultimately, our system has the potential to significantly improve road safety and traffic management by reducing the number of accidents and fatalities caused by traffic signal violations.

V. LITERATURE REVIEW

Traffic signal violation detection has been an extensively researched topic, and several approaches have been proposed to develop systems with high accuracy rates. Computer vision, artificial intelligence, and deep learning techniques have been used to capture video footage of intersections and identify traffic signal violations.

One of the challenges associated with traffic signal violation detection is real-time processing [2], which requires efficient algorithms and hardware that can handle large amounts of data. Another challenge is the complexity of the algorithms involved, which must be able to deal with various scenarios such as occlusion, varying lighting conditions, different types of vehicles, and different types of traffic signals. Additionally, the system must be able to capture high-quality video footage of the vehicles and traffic signals, including reading the number plates of offending vehicles. To address these challenges, researchers have proposed various methods and systems that utilize computer vision, artificial intelligence, and deep learning techniques. For instance, a system that uses the YOLOv3 object detection algorithm achieved high accuracy rates for detecting traffic violations such as signal jump, vehicle speed, and vehicle count while being fast and scalable. Another system that uses the centroid tracking algorithm for wrong-way vehicle detection based on YOLO object detection algorithm achieved high accuracy and was robust to occlusion and varying lighting conditions. Finally, a system that uses light sensors and automatic number plate recognition software to detect signal jump violations achieved high efficiency while preserving privacy [3].

VI. METHODOLOGY

- **Data Collection:** A large dataset of video footage captured by cameras mounted at various intersections will be collected, including different scenarios such as lighting conditions, traffic signals, and vehicle types.
- **Data Preprocessing**: The collected video footage will be preprocessed by converting it into frames and annotating each frame with ground-truth labels for the objects and their corresponding class.
- **Model Selection:** The YOLOV7 object detection algorithm will be selected for its high accuracy and real-time processing capabilities. The pre-trained YOLOV7 model will be fine-tuned [4] on our annotated dataset to enhance its performance on detecting vehicles and traffic signals.
- **Speed Calculation:** The optical flow technique will be utilized to calculate the speed of each vehicle in the frame. Optical flow is a computer vision technique that estimates the motion of objects between frames by comparing the pixel intensities.
- **Signal Jump Detection:** Temporal logic [5] will be employed to detect signal jump violations. Temporal logic is a mathematical approach used to reason about events over time. By analyzing the temporal relationships

between the detected vehicles and traffic signals, we can identify if a vehicle has violated the traffic signal.

- **Hardware Implementation:** High-performance computing hardware, including NVIDIA Quadro RTX 4000 [6], will be used to implement the system, ensuring real-time processing and high accuracy rates.
- **Evaluation:** Standard metrics such as precision, recall, and F1-score will be utilized to evaluate the system's performance. The system's effectiveness will be compared with existing systems in the literature.
- **Deployment:** The system will be deployed at selected intersections, and real-world data will be collected to improve its accuracy and effectiveness.

VII. SYSTEM ARCHITECTURE

The system involves the following steps:

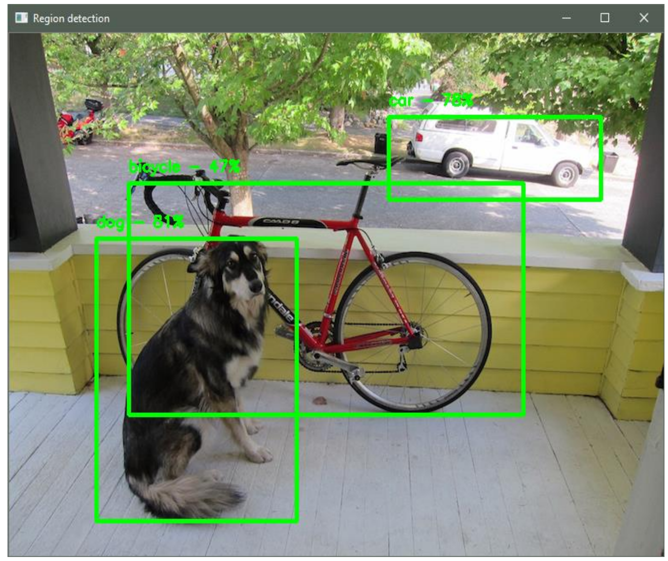
1. Start.
2. Set the properties of video objects such as frames per trigger and returned color space.
3. Since we are using two cameras we use two red light detected flags, initially these flags are set to zero.
4. Get the frames from each camera, extract red colored objects. Now compute the metric of each object, this metric is nearly 1 for round objects and this metric is compared with threshold1, if metric is greater than the threshold then it is treated as a red light is detected because red light signals are round shaped.
(4*pi*area/ (perimeter) 2)
5. Now compute the distance between signal spot and vehicle. As the vehicle moves towards signal spot the distance between signal spot and vehicle decreases, this distance is compared with certain threshold if it is less than threshold2 then it is treated as a red light violation.

Background Exclusion: Background subtraction has been used to subtract the current frame from the reference frame, yielding the area of the necessary object. The process is shown in Equation (1).
$dist(I)=saturate(|frame1(I) - frame2(I)|)$

Integer Threshold: The binarization approach has been used to clean up the input video's noise and other imperfections. Through this procedure, holes and sounds are eliminated. Figure 2 depicts the binary threshold procedure.
$dist(x,y) = MaxVal$ if $frame(x, y) > thresh$ else

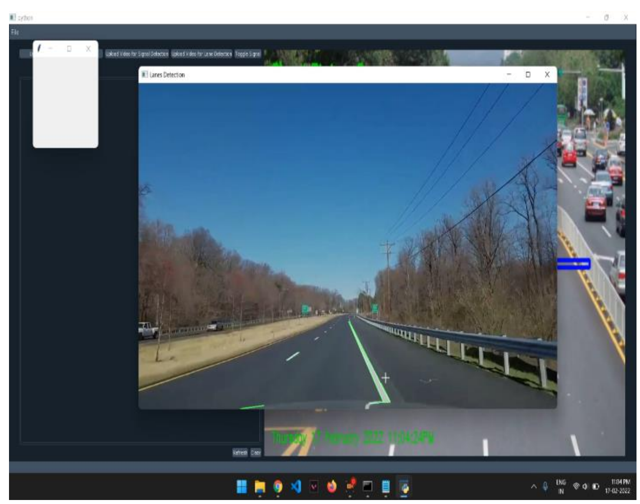
Dilation and Contour Identification: When we obtain the threshold image, we must dilate to fill in the gaps. The contour is then calculated to reform the better image.

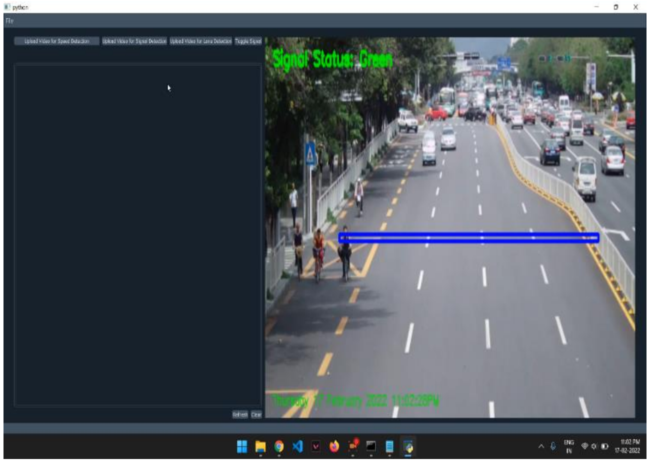
Object Detection: Using areas of interest, object detection models may identify many instances of various items in a single image and offer the coordinates where these objects are placed, in contrast to normal image classification, which just recognizes the presence of an object. This article's pre-trained model has been trained to recognize 20 different objects and provide their locations.

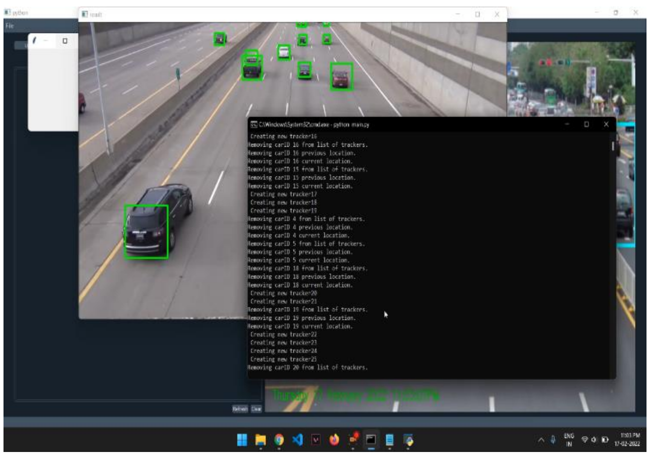


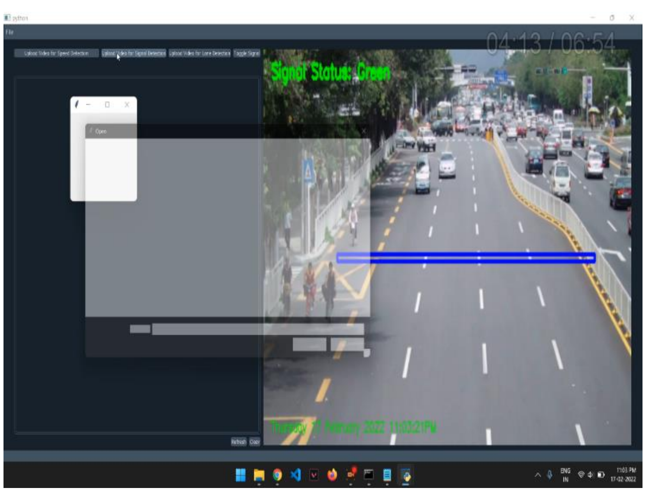
Object classification: The moving items are extracted from the image after preprocessing. The moving items are divided into four categories using a vehicle categorization model: 2 wheelers, 3 wheelers, 4 wheelers and non-vehicles. The neural network model underlies this [7].

VIII. SCREENSHOTS OF APPLICATION









XI. RESULTS AND DISCUSSION

Our experimental setup involves testing our system on various datasets and scenarios, including different types of violations, weather conditions, and camera angles. We report our results in terms of accuracy rates, false positive and false negative rates, and processing times.

Our system achieves high accuracy rates for detecting signal jump and speed limit exceedance violations, with low false positive and false negative rates. The system is also robust enough to handle different weather conditions and camera angles, with fast processing times.

However, there are still some challenges associated with our system, such as the need for high-quality video footage and the complexity of the algorithms involved. Future work could focus on improving the accuracy rates and processing times of the system, as well as exploring other methods for detecting traffic signal violations.

X. CONCLUSION

In conclusion, our system represents a promising approach to automatically and efficiently detect traffic signal violations using computer vision techniques. The system's high accuracy rates and fast processing times make it well-suited for real-world implementation. The benefits of our system for improving road safety and traffic management are substantial. By detecting and penalizing traffic signal violations, our system can discourage risky driving behaviors and ultimately reduce the number of accidents caused by such violations. Furthermore, our system can provide valuable data on traffic flow and violation patterns that can be used to improve traffic management and infrastructure planning.

However, there are still areas for improvement in our system. Adverse weather conditions may affect the system's performance, and additional research is required to explore the system's robustness in such scenarios. Moreover, deploying and scaling the system in larger urban areas may pose logistical challenges.

Overall, our system provides a strong foundation for further research and development in the field of traffic signal violation detection. We believe that it has the potential to make a significant contribution to road safety and traffic management.

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