A Survey on Real-Time Traffic Monitoring and Speed Violation Detection System using Yolov8 and Centroid Tracking

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Abstract: **Urban traffic congestion presents significant challenges that require efficient and intelligent management solutions. Traditional traffic monitoring methods lack precision and adaptability, especially under varying conditions. The system includes a camera array for data collection, a data processing unit, and a user interface for real-time monitoring. Our solution employs YOLOv8 for accurate vehicle detection and classification and is demonstrated through rigorous testing. The system offers a robust framework for enhancing urban traffic management, reducing congestion, and improving road safety. Vehicle counting is a process to estimate traffic density on roads to assess the traffic conditions for intelligent transportation systems (ITS). It is difficult to quickly and precisely perceive and recognize vehicle sorts because of the close partition between vehicles in the city and the hindrances perspectives of the image or video picture, counting photos of vehicles. We have attempted to resolve this issue by utilizing the most recent YOLO algorithm. DEEPSORT is a computer vision tracking algorithm that simultaneously tracks and assigns an ID to each object. Intelligent traffic monitoring and management based on computer vision technology can provide functions such as illegal behavior monitoring and traffic flow optimization by processing and analyzing image data in traffic roads, improving the level of traffic management and road traffic safety.**

Keywords: **Object Detection, Image Classification, Vehicle Counting, Tracking, Speed, Real-Time Traffic Monitoring, DEEPSORT, YOLOv8.**

INTRODUCTION

The incidence of traffic accidents has grown into a major issue due to the exponential development of both the population and the number of vehicles. To lessen the impact of these occurrences, immediate and efficient traffic control measures are required This can achieve monitoring and analysis of vehicle driving status, manage traffic from multiple dimensions, reduce manual intervention, and improve the efficiency of monitoring and management. For detected traffic conditions, timely feedback on traffic anomalies can be provided, facilitating relevant personnel to take corresponding management measures in a timely manner. The continuous maturity of computer vision technology has further reduced deployment and maintenance costs, and has obvious advantages in intelligent traffic monitoring and management.

Vehicle detection and speed estimation using YOLO (You Only Look Once) is a popular computer vision method for traffic flow analysis. YOLO is a deep learning algorithm that can detect objects in real time by splitting the image into multiple meshes and predicting the class and hull of each object in each mesh. This method has been successfully applied to vehicle detection and enables accurate and efficient identification of vehicles on roads and highways scientific methods.

Besides detecting vehicles, YOLO can also be used to estimate their speed. By plotting the envelopes of detected vehicles over multiple video frames, the algorithm can calculate the distance traveled by each vehicle and estimate its speed. This information can be used for traffic flow analysis, traffic safety planning and even to automate toll collection systems. Overall, vehicle detection and speed estimation using YOLO has become an important tool in traffic engineering and traffic research, offering a more accurate and efficient way to collect data on traffic patterns and vehicle behavior on the roads.

LITERATURE SURVEY

Bhatia, A., et a (2019) provides a comprehensive literature review of vehicle detection and speed estimation techniques for autonomous driving. The paper covers a wide range of techniques and algorithms, including traditional machine learning, computer vision, and deep learning techniques.

Li, Z., Huang, Y., Guan, Q., Wang, Z., & Li, M. (2018) present a deep learning-based approach for real-time vehicle detection and tracking in aerial video surveillance. The You Only Look Once (YOLO) framework is the foundation for the convolutional neural network (CNN) architecture the authors suggest for vehicle identification. The research also presents a method for tracking the observed cars across frames based on the Kalman filter. The suggested method performs well in real time and with high accuracy on a dataset of aerial footage that is publicly accessible.

Gao et al. presented a survey of deep learning techniques applied to traffic monitoring, dis-cussing challenges and future research directions for improving real-world performance. Another group of researchers integrated the YOLO (You Only Look Once) v8 model with Optical Character Recognition (OCR) for traffic violation system.

Deng, X., Yin, J., Guan, P., Xiong, N. N., Zhang, L., & Mumtaz, S., introduced the study suggests a deep learning method that makes use of Convolutional Neural Networks (CNN) to identify certain traffic infractions using the YOLO object detection framework. These violations include things like signal running, vehicle acceleration, and different kinds of vehicles in the region.

Kumar, P. (2020) presents a novel method for vehicle detection and speed estimation that combines deep learning and sensor-based approaches. The proposed method consists of two stages: object detection using a deep learning algorithm and speed estimation using a sensor-based approach. In the first stage, the authors use the YOLOv3 object detection algorithm to detect vehicles in the input image. The authors fine-tune the YOLOv3 algorithm on a custom dataset of vehicle images to improve its performance on vehicle detection. In the second stage, the authors use a sensor-based approach to estimate the speed of the detected vehicles.

METHODOLOGY

The flow chart describes the whole processing steps of the research article. The research article includes two types of modules in this article which has its own processing methods to detect the output

Pre Processing:

It involves three main steps:

Frames Conversion: In order to apply the YOLOv8 algorithm, the input video is typically divided into frames. Each frame represents a single image that will be processed by the model. This step ensures that the video is broken down into individual images for object detection and tracking.

Integrated CNN Model: YOLOv8 utilizes a convolutional neural network (CNN) as its backbone architecture. The CNN model is responsible for extracting features from the input images, which are then used to detect and classify objects. The integrated CNN model plays a crucial role in the accuracy and performance of the YOLOv8 algorithm.

Object Detection: The core objective of YOLOv8 is to detect objects in the input images. This is achieved through a combination of bounding box regression and class prediction. The model predicts bounding boxes that tightly enclose the detected objects and assigns class probabilities to each bounding box, indicating the likelihood of the object belonging to a specific class. During the preprocessing stage, the frames are converted, the integrated CNN model is utilized to extract features, and the object detection process is performed to identify and classify objects in the images.

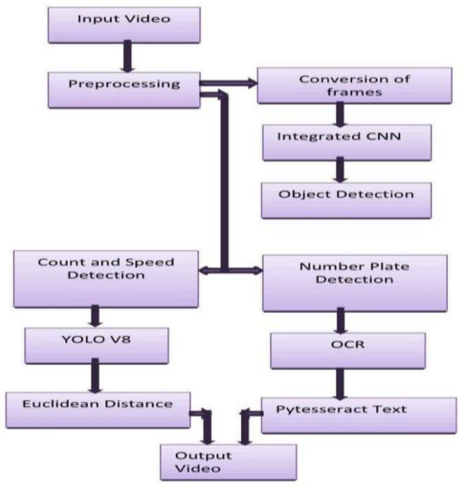

Fig-1 Activity Flow Diagram

Yolo V8: It takes an input image or video and uses the YOLOv8 model to identify and track objects of interest. The methodology of YOLOv8 involves dividing the input image into a grid and predicting bounding boxes and class probabilities for each grid cell. These predictions are then refined using anchor boxes and non

-maximum suppression to eliminate redundant detections. The project likely involves pre-training the YOLOv8 model on a large dataset, fine-tuning it on specific object classes, and implementing additional functionality for tracking, counting, and speed estimation.

OCR (Optical Character recognition): It utilizes theYOLOv8 model to detect license plates in images and then applies optical character recognition (OCR) techniques to recognize the characters on the detected plates.

This project is composed of several components: Camera Array, Data Processing Unit, and Historical Data Visualization. The Camera Array collects real-time traffic data, which is then processed by the Data Processing Unit. The Machine Learning component performs vehicle detection and classification on the processed data. The user interface enables visualization and management of real-time traffic data.Historical data visualization provides comprehensive analysis and visualization of historical traffic data, facilitating informed decision-making and predictive analytics.

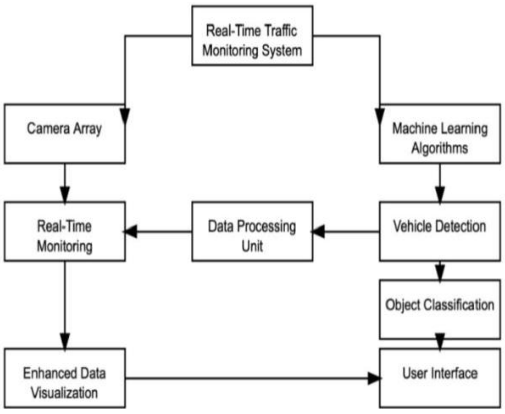

Fig-2 Real-Time Traffic Monitoring System

A. Camera Array

The Camera Array collecting real-time traffic data using advanced 2D camera technology. By providing a comprehensive view of traffic patterns and vehicle movements, the Camera Array ensures a reliable and continuous flow of information for further analysis and visualization.

B. Data Processing Unit

The Data Processing Unit prepares the raw data collected by the Camera Array, including data generation, insertion, and management. PostgreSQL is used for historical traffic data storage and management.

C. Historical Data Visualization

The Historical Data Visualization component provides comprehensive analysis and visualization of historical traffic data.

Vehicle Count and Average Speed: Visualize the vehicle count and average speed over time using line charts and area charts.

Vehicle Type Distribution: Presents the distribution of vehicle types using pie charts.

Lane-wise Vehicle Count: Displays the vehicle count per lane using stacked bar charts.

Traffic Density Heatmap: Represents traffic density using color intensity on a heatmap.

Data Export: Enables users to export the visualized data in CSV or PDF format for further analysis.

These features enable users to explore and analyze historical traffic data from different perspectives, facilitating informed decision-making and predictive analytics.

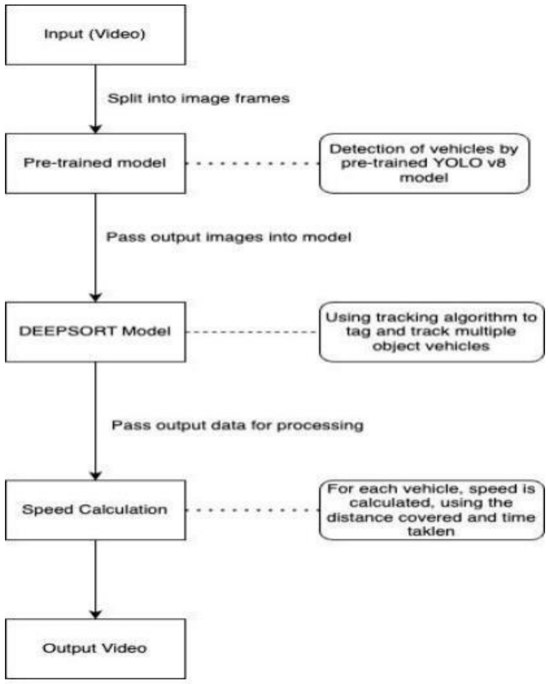

Fig-3 Activity Flow and Architecture Diagram

D. Vehicle Detection

The processed frames are then sent to the YOLO v8 model, which automatically detects the vehicles. An image is used as input to the YOLO which uses a simple deep convolutional neural network to locate images and objects.

E. Speed Calculation

Finally, the speed of the vehicle is calculated using the kinematic equation:

$$v = \Delta d / \Delta t$$

where Δd is the distance between the vehicle in the current frame and the vehicle in the previous frame, and Δt is the time elapsed between the two frames.

F. Tagging and tracking Vehicles using the DEEPSORT algorithm

For the purpose of keeping track of the vehicles that were discovered in the phase prior, we make use of an open- source algorithm known as DEEPSORT. DEEPSORT is a computer vision tracking algorithm that simultaneously tracks and assigns an ID to each object. DEEPSORT is an addition to the SORT (Simple Online RealTime Tracking) algorithm. DEEPSORT improves tracking efficiency by reducing identity switches by incorporating an appearance descriptor into the SORT algorithm.

RESULTS & DISCUSSION

Our model uses YOLO to detect vehicles and estimate their speed using the distance-time equation. The overall system workflow includes a video feed that is sent to the system via a camera or as a file. Videos are split into frames using the OpenCV open-source library. Then each image was passed to a pre-trained YOLO v8 model to detect the vehicles we needed. The output images are then passed through a DEEPSORT algorithm that will tag objects making it easier to track multiple objects. We take two points of image A and B as reference. As vehicles pass through these points, we estimate the time traveled and the distance traveled as the distance between points A and B, after using appropriate methods to convert the distance from pixels to meters. We then use the distance-time formula to estimate the speed. The model shows improved accuracy in all vehicle detection scenarios compared to standard benchmarks using YOLO v7. It also shows an increased ability to detect unusual or uncommon vehicles due to custom training.

Table 1 YOLO Mean Average Precision for Various Versions Compared

Yolo Version	Year Released	Mean average Precision
YOLO V2	2017	21.6%
YOLO V3	2018	33.1%
YOLO V4	2020	43.5%
YOLO V5	2020	50.0%
YOLO V6	2022	51.3%
YOLO V7	2022	52.2%
YOLO V8	2023	53.3%

Accuracy

Accuracy is also an important indicator for measuring the performance of the YOLO algorithm, which is the ratio of the number of correctly matched prediction boxes to the total number of prediction boxes. The higher the accuracy, the better the performance of the algorithm.

Figure 4, shows the accuracy variation during the testing process.

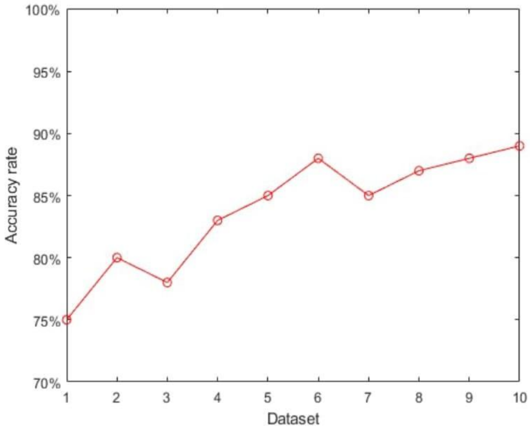

Fig-4 Accuracy testing situation

Accident Rate

The traffic accident rate is one of the important indicators for evaluating traffic safety. The lower the traffic accident rate, the higher the degree of road traffic safety. Figure shows the changes in accident rates before and after using computer vision technology for intelligent traffic monitoring and management.

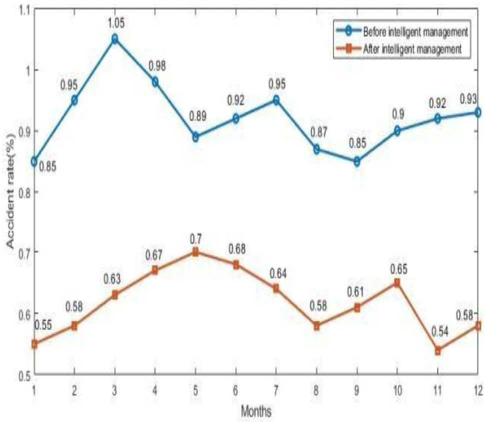

Fig-5 Comparison of accident rates

According to Figure 5, before using computer vision technology to achieve intelligent traffic monitoring and management, the average monthly traffic accident rate was 0.92%. After implementing traffic monitoring and management, the average monthly traffic accident rate was 0.62%, and the average monthly traffic accident rate decreased by 0.3%.

CONCLUSION

By using computer vision technology, various situations in traffic scenes can be monitored and analyzed in real- time, providing more efficient and safe traffic management and control. The use of advanced object detection and tracking algorithms in intelligent traffic monitoring and management can accurately extract the location, speed, and behavior information of traffic targets, automatically identify traffic violations such as running red lights and going against traffic, effectively maintaining road traffic order. Intelligent traffic monitoring and management can also perform traffic flow statistics and analysis, providing real-time traffic status and flow analysis for traffic management departments, helping them solve traffic congestion problems, optimize signal timing and other traffic control strategies. This can improve traffic conditions, enhance traffic safety and the efficiency of traffic resource utilization, and promote the modernization and intelligence process of urban transportation operation.

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