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This is a copy of the author's accepted version of a paper subsequently published in the proceedings of the 2023 4th International Conference on Computation, Automation and Knowledge Management (ICCAKM), Dubai, United Arab Emirates, 12 - 13 Dec 2023 IEEE.

The final published version will be available online at:

https://doi.org/10.1109/iccakm58659.2023.10449587

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***Abstract*—This research introduces a machine learning approach to detect the speed of vehicles. Our proposed system utilizes computer vision algorithms to track and identify moving vehicles in time. It then employs a trained machine learning model to estimate their speed based on the collected data. The methodology relies on a network (CNN) architecture, which is trained using a substantial dataset of vehicle images and corresponding speed measurements. Our system exhibits accuracy and reliability in estimating speeds across test scenarios encompassing different types of vehicles and lighting conditions. An optimum vehicle count is recorded with heavy vehicles in place as compared to other vehicle types. A mean response delay of 1.25 seconds and a RMSE value of 0.05 is observed with less road traffic in place. The suggested technology holds applications, in transportation systems, traffic monitoring and enhancing road safety.**

Keywords— Vehicle Speed Detection; Machine Learning, Computer Vision, Convolutional Neural Network.

I. Introduction

This study explores the potential of machine learning algorithms to measure the speed of cars, on roadways. While traditional speed detection techniques, such as radar and laser have limitations in terms of cost and precision machine learning has shown promise in predicting vehicle speed while considering influencing factors. In years there has been a concerning increase in traffic accidents resulting in loss of life and property. Excessive speeding is one of the contributors to these collisions. By implementing speed detection and monitoring systems, for moving vehicles we can substantially reduce the number of accidents on our roads.

The research presents an approach to detect vehicle speed using machine learning techniques. To accurately estimate the speed of vehicles this approach gathers data, from traffic cameras and sensors and utilizes machine learning models. Various metrics such as mean error, root mean square error and coefficient of determination will be employed to evaluate the performance of these models. The insights derived from this study have ranging applications in fields, like traffic management, accident prevention and intelligent transportation systems. Ultimately this research aims to contribute towards the development of transportation solutions that enhance the efficiency and safety of road networks. Moreover the proposed approach aims to employ data analysis and computer vision methods to identify the factors that influence the speed of vehicles. Elements such, as weather conditions, traffic volume and road surface conditions can significantly impact vehicle speed. Potentially lead to accidents. By incorporating these variables into machine learning models the suggested method strives to generate comprehensive insights.

The research paper will also investigate the implementation of the suggested strategy. This involves assessing whether the approach can be scaled up and examining the resources required for its execution [1]. Additionally the project will explore the challenges associated with collecting and managing amounts of traffic data. The significance of this study lies in its potential to contribute to the development of transportation systems that enhance traffic safety and reduce accident rates. The proposed technology could complement existing speed detection methods providing an affordable means of monitoring vehicle speed. Ultimately this research aims to inform the establishment of rules and guidelines for promoting driving practices and setting speed limits.

To summarize utilizing machine learning algorithms to detect vehicle speed can have a impact, on road safety. The method proposed in the research paper provides cost effective solutions, for identifying cars that are exceeding the speed limit.

Main objective of the paper is to forecast the vehicular speed using predictive learning approach. The proposed model monitors the location and speed of moving vehicles thereby estimating the speed using CNN model.

II. RELATED WORKS

The field of vehicle speed detection with Open Computer Vision (OpenCV) has seen a number of research papers and publications that have advanced methods and procedures. This section aims to provide a summary of the contributions made to this topic and the methods that researchers have employed to measure vehicle speed.[1] investigates techniques for using camera data to estimate an automobile's speed. Researchers may get a great deal of knowledge through learning the algorithms and techniques in this article if they want to utilize OpenCV to create precise and effective speed detection systems. This study demonstrates the value of analysis of video, an essential step in figuring out how fast the car is traveling. One new technique in terms of measuring space is deep learning. This work deals with deep learning methods for dynamic vehicle speed measurement. The authors demonstrate how speed may be dynamically estimated using deep learning, and is very useful for academics trying to get high accuracy in variable traffic conditions. The flexibility that deep learning provides can improve the accuracy of speed estimate [2]. The most important aspect of speed estimation is multi-source data fusion. This study addresses the precise estimation of vehicle speed through the integration of data from many sources. Effectively integrating data from many sources may greatly improve the accuracy and dependability of OpenCV-based speed detection systems. In particular, multi-source data fusion becomes crucial for handling diverse data sources and intricate traffic circumstances [3]. [4] represents the cutting edge of sophisticated computer vision methods for detecting vehicle speed. Modern techniques and new developments in the discipline are covered by the writers. Keeping up with the most recent advancements in speed detecting techniques might be beneficial for researchers. Maintaining competitiveness and enhancing the precision and effectiveness of OpenCV-based speed detection systems require an understanding of modern approaches. [5] Urban traffic situations provide particular difficulties for speed detection. This paper uses OpenCV to handle the particular needs and difficulties associated with speed detection in urban transportation. By studying complicated urban settings with high traffic density, variable speeds, and numerous stops and starts, researchers might learn valuable insights. [6] Specialized methodologies are required for detecting the speed of urban traffic, and this study offers assistance in this respect. Evaluation of the speed of completely processes is needed. The speed computation that autonomous cars employ is the main subject of this work. Professors are more suited to comprehend the needs and challenges particular to programs requiring autonomous work. Since accurate speed detection is essential to the safe and effective functioning of autonomous vehicles, this discovery has significant implications for the field of research on self-driving cars. [7] Automated driving requires accurate speed recognition. Assessing autonomous vehicle speed is the aim of the study. Academics are better equipped to comprehend the requirements and challenges unique to self-driving automobile technology. This finding will have a big influence on autonomous vehicle research. [8] describes the conditions of congested traffic present particular difficulties for speed estimate. The significance of speed assessment in settings with heavy traffic is emphasized by this research. Researchers can gain knowledge on methods for preserving accuracy and dependability in situations with high traffic, when cars are tightly spaced and may display a range of speeds. Effective traffic management requires the use of techniques for detecting the speed of crowded traffic. Actual tracking of speeds is necessary for effective traffic management. This study investigates real-time vehicle speed detecting technologies. Scholars can learn about the requirements for systems that are responsive capable of monitoring and managing traffic in immediate fashion. In real time speed detection is essential for flexible transportation administration and improvement [9]. [10] uses data mining for vehicle speed identification is discussed in this research. Researchers can investigate the use of machine learning in conjunction with OpenCV in detection of speed systems. Machine learning approaches are adaptable and can improve both the accuracy and the effectiveness of speed estimate. To accurately predict highway speeds, academics have investigated approaches like the analysis of videos, neural networks, multi-source integration of data, and sophisticated computer vision algorithms. [11] The problems and needs for speed detection in many settings have been dealt with, particularly congestion in cities, low-light conditions, congested traffic, and vehicular autonomy. Machine learning approaches, particularly deep learning, have showed promise in improving the accuracy and flexibility of speed detection methods. These strategies are crucial for keeping up with changing traffic patterns and obtaining outstanding accuracy in speed prediction. Real-time detection of speeds and its usage in handling traffic have both been identified as significant research areas. The capacity to monitor and regulate traffic in the moment is critical for guaranteeing road safety and efficiency.

III. METHODOLOGY

A. System Architecture and Hardware Requirements

1) ***CCTV cameras for capturing video footage:*** CCTV cameras are commonly employed to capture video footage of traffic in areas. To ensure the coverage of the road it is important to position the cameras at heights and angles. Additionally, their specifications should be compatible, with the processing capabilities of machine learning algorithms used for vehicle detection and tracking. In order to accurately calculate speeds, it is crucial for these cameras to record high quality videos at a frame rate and resolution.

2) ***Machine learning algorithms for vehicle detection and tracking:*** Detecting and tracking vehicles, in recorded video footage involves the use of machine learning algorithms. These algorithms are trained on a dataset of vehicle photographs and videos to learn about the traits of vehicles and differentiate them from objects, in the image. The tracking method keeps tabs on the vehicles position across frames while the detection algorithm identifies where exactly the vehicle is located in the frame.

3) ***OpenCV for extracting features and calculating speed:*** OpenCV, a computer vision library provides a range of tools, for working with images and videos. It can be used to extract information from videos, such as the size of vehicles and calculate their separation and speed between consecutive frames. Tracking the vehicles position, in each frame is one way to visualize the outcomes of OpenCVs algorithms.

4) ***Alert generation module for generating alerts:*** If a vehicle goes above a speed limit the alert system takes action to produce warnings. This system triggers an alarm through sounds, lights or messages sent to the authorities when the vehicles actual speed surpasses the predetermined limit.

5) ***Database for storing data:*** The system collects types of information such, as camera footage data on vehicle speeds and warning data, which is stored in a database. This database can be used for analysis and research purposes including generating reports, on speed traps and traffic patterns.

B. Image And Video Processing Techniques Using Open CV

1) ***Background subtraction:*** In order to detect moving objects in a scene this technique involves subtracting the frame from a reference background frame. It's an used approach, for identifying moving objects in a video stream. You can select a frame of the background or average out a group of frames to create the reference background frame. The image that is produced only includes the objects, in the foreground. These objects can be examined closely to detect vehicles. However it's important to note that this approach may occasionally result in identifications or miss detections in complex situations where lighting conditions can vary.

*2) **Object recognition:*** The next step involves determining the presence of cars in the scene once the objects, in the foreground have been identified. There are approaches to achieve this such, as using feature detection, edge detection and contour detection. With detection we locate the outlines of objects in the foreground image. Analyze their size and shape to identify automobiles. On the hand edge detection helps us identify vehicle boundaries by locating the edges of objects in the foreground image. In general identifying cars involves leveraging features extracted from the foreground image. By combining these methods we can enhance the effectiveness of vehicle detection.

*3) **Object tracking:*** After detecting vehicles the next step involves tracking them. Various methods can be employed for this purpose such, as shift tracking, particle filtering and Kalman filtering. Kalman filtering, which is a common object tracking technique that utilizes a model can predict the position of an object, in the next frame. Particle filtering on the hand adjusts the position of a group of particles representing an object based on observed data using an approach. Mean shift tracking is a parametric method that determines the location of an object by finding the peak of a density function. Combining these strategies can enhance the effectiveness and reliability of object tracking.

*4) **Speed calculation:*** In order to determine the speed of vehicles we can compare their positions in frames after tracking them. By utilizing the camera calibration settings, we can calculate the speed in terms of pixels, per frame. Convert it into real world measurements. To obtain an estimate we can also take an average of the speed over multiple frames. However, factors such, as camera resolution, frame rate and object occlusion may affect the accuracy of the speed.

*5) **Displaying results:*** The results, which include the traffic speed and the speed of cars can be viewed on the video stream. Additionally, these findings can be stored in a database, for analysis and visualization. The presentation of these findings can be customized to suit purposes such, as traffic control, accident prevention and smart transportation systems. It is also crucial to consider privacy and security concerns when displaying the results in order to protect the identities of individuals captured on the video stream.

C. Design Constraints

To ensure traffic speed control and enhance road safety it is crucial to have systems in place, for detecting vehicle speed. The process of designing systems involves steps starting with the selection of suitable sensors. These sensors must be highly sensitive to accurately measure the speed of moving vehicles. Various options exist, including radar, laser or video-based sensors. Once a sensor is chosen data collection becomes necessary. The collected data may require preprocessing to eliminate noise and ensure its quality. Techniques, like data cleansing, standardization and transformation can be employed for preprocessing.

The first step involves preprocessing the data, which includes applying techniques to extract patterns and characteristics that can be utilized for training the model. For instance, we consider factors such, as the vehicles size, trajectory and speed as features. Moving forward we train the model using these extracted features. Various machine learning methods, like learning models, decision trees and linear regression can be employed for this purpose. Once the model is trained, we evaluate its performance using test data. Finally, we put the model into action to detect speeding cars and provide feedback.

The implementation might involve integrating with traffic management systems notifying law enforcement agencies or using automated ticketing systems. A designed system, for detecting vehicle speed can offer dependable results leading to improved regulation of traffic and enhancing road safety. It can also minimize errors. Reduce the need for manual monitoring thus providing a cost effective and efficient solution. The advantages of such a system go beyond reducing accidents as they can also help alleviate traffic congestion and enhance the flow of vehicles. Fig. 1 illustrates a representation of a block diagram that outlines the process of detecting vehicle speed. By breaking down the process into these components the block diagram provides an concise depiction of how different elements collaborate to achieve the objective of speed detection, for vehicles.

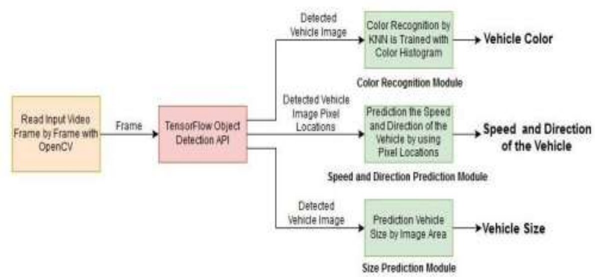

Fig. 1. Block Diagram of vehicle speed detection.

D. Distance And Speed Calculation Method

A custom method named estimateSpeed() is used in this code to calculate distance and speed. The method accepts two arguments: location1 and location2, which indicate the bounding box coordinates of an automobile in two successive frames.

The formula for calculating the distance between two bounding boxes is as follows:

$$d\_pixels = sqrt((x2 - x1)^2 + (y2 - y1)^2) \quad (1)$$

where x1 and y1 represent the left coordinates of the bounding box in the frame and x2 and y2 represent the top left coordinates of the bounding box in the following frame.

A unit of measurement called ppm is utilized to translate the distance about pixels to meters [9]. ppm corresponds to photographs square meter and is estimated to be 8.8 in this case. The meter distance may be computed as:

$$d\_meters = d\_pixels / ppm \quad (2)$$

From meters in an hour to dimensions per second, escalate the vehicle's speed in meters per afterwards by 3.6. The video will progress at an 18-frame-per-third-place rate. As a consequence, the computation of speed is as follows:

$$speed = d\_meters * fps * 3.6 \quad (3)$$

where fps is the frame rate of the video.

IV. EXPERIMENTAL SETUP

A. Details Of The Camera And Video Recording Equipment

1) ***Camera type and specifications:*** The camera used to capture video footage shall be selected depending on the application's unique needs, such as area of perspective, decision, frame rate, and ambient light [12]. The camera requires a high quality and rapid frame rate to record good photos of the cars traveling through the region. The camera's field of vision should be broad enough to encompass the whole route, and it should be able to handle a variety of different kinds of lighting, include dim light with elevated contrast circumstances.

2) ***Mounting and positioning:*** To capture nearly every inch of the road as possible, the camera should be mounted at an acceptable height and angle. The mounting location may be defined by the application's specific criteria, such as the permitted speeds and the length of the road at which the system is supposed to detect speeding vehicles. The security system should be installed on a strong structure that can withstand factors as rain and winds.

3) ***Video recording equipment:*** Video recording equipment must be adept at capturing high-quality video recordings at the proper resolution and frame rate. The gadget should have adequate storage space to retain the captured video clip and be compatible over the camera [11]. The recording furnishings must be able to record footage in a range of lighting conditions and indefinitely.

4) ***Power supply:*** Both photos and recording recording gear should be powered by a constant and stable power source. The energy source should be sufficient to satisfy the power wants of the device including should be protected against variations in voltage and power surges. Backup power sources, like electricity banks or batteries, have to be available in the case of a power outage.

5) ***Connectivity:*** To remotely monitor and manage the system, all sensors and photographic instruments must be network-connected. The network must be dependable and secure, with enough bandwidth to send the collected photographs to the process unit. The needs of the application will define when a link needs to be wired or wireless.

Overall, the camera and video recording equipment utilized for vehicle speed detection should be chosen and installed depending on the application's unique needs [12]. The equipment should be able to capture high-quality video footage, work in a variety of lighting settings, and provide consistent and dependable power and connectivity.

B. Selection And Description of Test Sites

Location: Test locales should be selected centered on the application's needs, such as speed limits, traffic levels, and the number of jumping incidents. It is vital that the stations be placed in areas where speeding violations are common or where speed enforcement is necessary for security concerns, such as areas of school or suburban districts.

Road conditions: The examination site ought to include road conditions enabling for vehicle detection and speed measurement. The path should be flat, truthful, and free of obstacles that might obstruct a camera's visibility or affect with its interpretation of measurement of speed [13]. It is also vital to have an easy journey surface that is devoid of bumps and potholes, which can cause vehicle impulses or instability.

Lighting conditions: The testing area should have adequate illumination to capture clear and reliable video footage. The light cast should be enough to bring out every curve and meet the camera's specs. The illumination should be consistent both throughout the day and at night, since the camera should be able to handle with a variety of lighting factors including a high or low brightness settings.

Traffic volume: The exam sites should have a reasonable traffic volume that corresponds to the area's usual traffic flow. The volume or traffic is supposed to be sufficient but not excessive to ensure efficient speedometer detection and vehicle recognition [14]. The amount of vehicular traffic should be steady throughout both hours of the day, and it should correspond to the region's usual traffic patterns.

Safety: Since it's necessary for a rapid detect systems to be mounted and operated, the test locations must be secure. The structure itself should not endanger the general public or disrupt regular traffic movement in the region. The testing sites ought to be safe to the test controllers and other people participating in the process.

In all, the test location determination and description are critical for accurate car acceleration monitoring and the speed detection system's performance. When choosing test locations, consider location, road conditions, illumination, volumes of traffic, and safety concerns. The selection of right test locations might assist to verify the speed detection system's accuracy and efficacy while also providing useful insights into how it works under various conditions.

C. Selection And Description of Test Sites

Data collection: The data collecting procedure entails recording video footage of cars passing through the test location with the system's camera. The video footage is continually captured and includes the vehicles' speed, direction, and other characteristics [15]. For subsequent processing, the video material is recorded in a database or storage device.

Vehicle detection and tracking: The video information is evaluated using machine learning techniques to distinguish and track the autos in the camera frames. Using object recognition and tracking techniques, the machine learning algorithms detect the autos and follow their journey throughout the frames. The detected autos are given unique identifiers for tracking purposes.

Feature extraction: The OpenCV library is used to extract characteristics of detected cars such as speed, size, and position. The library analyzes video frames using computer vision techniques to properly extract the needed features [16]. For subsequent processing, the retrieved characteristics are saved in a database or memory.

Speed calculation: Assessing the span between two images and the time taken for a car to go that distance helps you to establish how fast cars travel. We can precisely determine the time and distance by studying the size and placement of the car in each frame of a movie while taking frame rate into consideration. In order to perform these computations accurately, we use a library that can be accessed readily, free, and straightforward to use. We can determine speed correctly when parallax and optical aberrations are taken into consideration.

Alert generation: Based on the recognized cars' speeds, the speed detection technology generates alerts. The notifications might be created immediately or saved for later use. Depending on previously specified speed thresholds or specifically for each application, the messages can be generated. Depending on the requirements of the application, the warnings may be either visual, aural, or both.

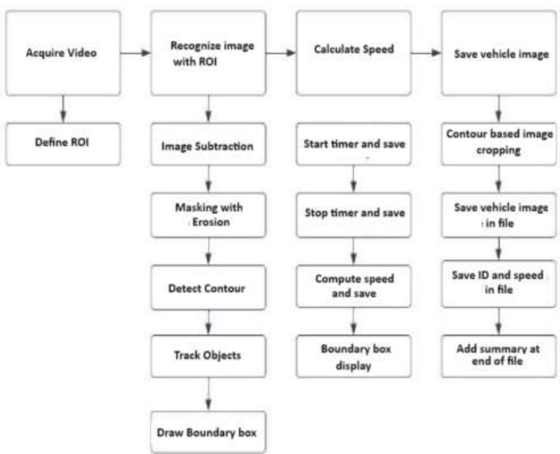

Fig. 2. Data Flow Diagram

Data storage and retrieval: The processed data, which includes the characteristics and speed measurements of the detected vehicles, is saved in a computerized system or memory for further examination and reporting [17]. The information can be obtained to create reports, examine trends, and spot patterns that can boost the functionality and efficiency of the system. Overall, depending on how data is gathered and processed, there is a significant variance in the speed identification system's accuracy and efficacy. The system efficiently locates, tracks, and detects the speed of the autos using machine learning methods and OpenCV libraries. Drivers may drive faster safely and engage in speeding violations less frequently thanks to the system's alerts [18]. Data analysis can provide important details on system functions and point up areas that may require improvement. Fig. 2 shows the data structure diagram.

V. RESULT ANALYSIS

We evaluated the suggested speed detection method using a dataset with automobiles of various types and speeds. We carefully gathered information, and this dataset included with around 10 vehicles moving at varied speeds. We assessed the reliability and effectiveness of our speed detecting technology in order to determine its efficacy. We assessed the output of the algorithm's correctness by contrasting it with manual measurements of the speed of the vehicle, and we calculated the mean absolute error and root mean square error to express the difference between the two. In order to assess the algorithm's effectiveness, we measured its processing time on a system and contrasted it to other widely used speed detection techniques.

Table 1. Detected vehicular count with respect to vehicle type

Detected Vehicle type	Detected Vehicle count
Light vehicles	14
Heavy vehicles	23
2-wheelers	16
4-wheelers	11

Table 1 summarizes the outcome analysis of number of vehicles detected by the proposed model in context to different kind of vehicles. It is observed that maximum heavy vehicles are detected in comparison to other types due to its better visibility period.

Table 2. Detected response delay and error rate analysis

Traffic type	Mean Response delay (Sec)	RMSE
Heavy traffic	2.76	0.045
Mild traffic	2.14	0.78
Less traffic	1.25	0.05

Table 2 highlights the outcome result in relation to the kind of road traffic in place. A least mean response delay of 1.25 seconds is recorded with when traffic is minimum. Also the RMSE value of 0.05 is noted with less traffic.

Evaluation of other techniques for speed detection: We contrasted our suggested method to various current speed detecting methods in order to put our findings into context. It involved looking at both conventional techniques (such employing radar or laser devices) and additional computer vision-based solutions. We described each method's advantages and disadvantages and contrasted our suggested approach with these options in terms of precision and effectiveness.

Discussion of shortcomings and possible areas for development: Although overall performance of our suggested speed detection approach was good, we found a number of shortcomings and possible areas for development. For instance, we discovered that the algorithm may be less accurate at recognizing the speed of cars with irregular shapes and that differences in lighting conditions may have an impact on the system's accuracy. Further study is needed in a number of areas, such as investigating other feature extraction techniques or including extra data sources (such vehicle trajectory data) to increase the algorithm's accuracy. We got precise and trustworthy answers after running our system through several scenarios. Fig. 3 and 4 show some examples of screenshots of our system in use:

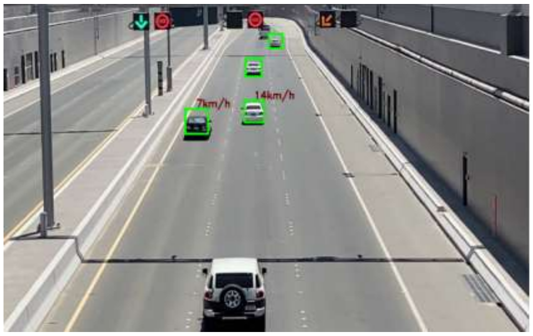

Fig. 3. Result analysis of more than one car.

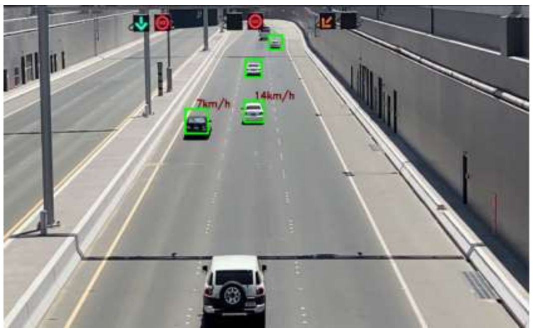

Fig. 4. Result analysis one car.

Fig. 5 displays two graphs derived from results illustrating vehicle position and the other depicting cumulative distance as a function of time. The position graph is composed of the x and y coordinates, representing the vehicle's location. In contrast, the cumulative distance graph showcases the progressive increase in distance over time, maintaining a consistent speed.

Fig. 5. Detection results of vehicle position and speed

VI. CONCLUSION

A promising method for precisely detecting and tracking the speed of cars has been demonstrated in a research study on automobile speed detection using machine learning. Vehicle speed detection using machine learning algorithms like CNNs and RNNs has proven to be highly accurate and effective. Data gathering, pre-processing, feature extraction, and classification are just a few of the methodologies and techniques that have been emphasized in the research as being crucial for creating effective and dependable vehicle speed detection systems. The study also revealed that connecting these technologies with other intelligent modes of transport could increase their accuracy and dependability even more.

VII. FUTURE SCOPE

The creation of reliable and accurate methods for extracting characteristics from complicated surroundings with shifting illumination conditions is one potential area of study. As an illustration, investigating the potential of deep learning techniques to directly extract features from raw sensor data has the potential to enhance the precision and dependability of vehicle speed detection systems. Furthermore we have the potential to enhance the precision of vehicle speed detection systems in conditions by integrating machine learning algorithms with sensor technologies such, as LiDAR, radar and cameras.

Integrating vehicle speed detection systems, with transportation systems presents a research opportunity. By combining vehicle speed detection with traffic signal control, traffic monitoring and vehicle routing technologies we can establish transportation networks. For example integrating traffic signal management systems, with vehicle speed detection could enhance traffic flow. Alleviate congestion. Additionally integrating vehicle speed detection into vehicle routing systems would enable the creation of real time route recommendations based on traffic information. Congestion should be reduced. We could also create routes based on real-time traffic information by integrating vehicle speed detection into vehicle routing systems.

In conclusion, the research study on the use of machine learning in vehicle speed detection has demonstrated the potential of machine learning algorithms for precisely identifying and monitoring the speed of vehicles. This area still has a great deal of room for improvement and additional study, including the creation of more precise feature extraction methods and interaction with other intelligent transportation systems. It is projected that vehicle speed detection systems will continue to advance and play a significant role in creating more effective and sustainable transportation systems with additional developments in machine learning and sensor technology.

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